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Organisational teleology 2.0: Grounding biological purposiveness in regulatory control

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Abstract

This paper critically revises the organisational account of teleology, which argues that living systems are first and foremost oriented towards a goal: maintaining their own conditions of existence. It points out some limitations of this account, mainly in the capability to account for the richness and complexity of biological systems and their purposeful behaviours. It identifies the reason of these limitations in the theoretical grounding of this account, specifically in the too narrow notion of closure of constraints, focused on self-production. It proposes to ground an organisational account of biological teleology in the capability of living system not just to produce and replace their parts, but to control their own internal dynamics and behaviours in such a way as to maintain themselves. This theoretical framework has two advantages. It better captures the distinctive features of biological organisations and consequently the richness and active nature of their purposeful behaviours. By doing so, it makes it possible to apply this framework beyond minimal theoretical models to real biological cases.

KEYWORDS
biological goals, closure, integration, organisation, regulation

1 | INTRODUCTION

Living systems are made of soft components that are subject to constant degradation and transformation and need to be continuously replaced or repaired. They maintain themselves far from equilibrium with their environment through a host of mutually dependent activities. These include procuring and taking in resources (matter and energy), processing them, and using them to select and run their internal processes in ways that are appropriate to circumstances, to build and repair themselves, and to generate, modulate and sustain behaviours that allow them to move in and interact with their environment. Living systems do not operate under a fixed set of conditions but exhibit diverse activities under varying circumstances to cope with continuously changing conditions in their environment but also within themselves. Unlike inert objects, they cannot shut down their own processes and just persist in their environment, or even keep doing the same thing. To realise a network of components and processes that supports their existence and activity, they need to continuously act and to do so in multiple ways.

The ultimate aim of the organisational framework in biology (Bich et al., 2016; Moreno & Mossio, 2015), built upon the philosophical and theoretical tradition of biological autonomy (Piaget, 1967; Rosen, 1972; Pattee, 1972, Varela et al., 1974; Kauffman, 2000), is to provide an understanding of these features of biological systems by adopting a perspective primarily focused on the organism, its physiology and behaviour, rather than evolution. This framework characterises the activities of a living system in maintaining itself as fundamentally oriented towards a goal: the maintenance of the system. The organisational account of biological teleology was introduced by Mossio and Bich in 2014 to ground the intrinsic purposiveness of living systems in their organisation (Mossio & Bich, 2017). It argues that living systems, as self-maintaining systems, are first and foremost oriented towards a goal, which coincides with their own conditions of existence. Two distinctive features of this account make it stand out from what is commonly done when addressing biology teleology: (1) it naturalises teleology in terms of the current organisation of a living system and (2) it does so by considering the whole system as goal oriented rather than specific traits. One of the aims of this kind of approach is in fact to provide theoretical foundations to the organisational account of functions developed few years before by Mossio et al. (2009). It does so by considering functions as teleological in the context of a purposive system that harbours them, not taken individually.

The theoretical basis for the naturalisation of teleology in terms of organisation is constituted by the notion of closure of constraints (Montévil & Mossio, 2015; Moreno & Mossio, 2015), a recent development of the idea of *organisational closure* first introduced by Jean Piaget (1967) and further investigated by Rosen (1972), Maturana and Varela (1980, see also Varela, 1979). The conceptual core shared by the different versions of the notion of closure is the idea that a biological organisation is characterised as a closed (i.e. circular) network of processes of production in which each component is produced by others in the network, such that the network maintains itself despite the continuous turnover at the level of its parts and the continuous interaction with the environment.

The idea of teleology based on closure is focused on the activity of production and maintenance of components from matter and energy procured from the environment. It is minimalist as it focuses on a subset of the activities described in the first paragraph of this paper: a system is considered teleological because it realises a causal regime according to which it maintains itself by building and replacing its own components. The system exists simply by keeping operating this way. If it did not, it would die.

The aim of this paper is to critically analyse some limitations of this account, specifically in the capability to account for the richness and complexity of biological systems and their purposeful behaviours. It identifies the reason of the difficulties of capturing the distinctiveness of biological teleology in the narrowness of the theoretical framework employed in Mossio and Bich (2017) to ground teleology: the basic notion of closure of constraint. It proposes to revise the organisational account of biological teleology by grounding it in a richer theoretical framework that goes beyond the traditional idea of self-production to focus on regulatory control: i.e. the capability of living systems not just to produce and replace their parts, but to control their own internal dynamics and behaviours in ways that allow them to maintain themselves (Bich et al., 2016).

The organisational account of biological teleology and its differences with respect to other approaches to teleology are discussed in Section 2, while its limits are analysed in Section 3. Section 4 focuses on revising the theoretical foundations of the organisational framework in biology. It discusses the limitations of the notion of closure of constraint in accounting for the distinctive features of biological systems and proposes placing regulatory control at the very core of the theory of biological organisation. Based on the revised theoretical foundations of the framework, Section 5 provides a reframing of the notion of organisational teleology, aiming to better capture the richness and complexity of biological purposiveness while addressing some implications of this renewed framework. The main ideas are summarised in the conclusions (Section 6).

2 | ORGANISATIONAL TELEOLOGY

Teleological vocabulary is widespread in biology, for example when referring to various crucial notions, such as the function of parts, and phenomena such as physiological regulation, homeostasis, decision making, agency, behaviour, etc., which are considered in relation to goals. This is more than just a manner of speaking. Functions play an important role in biological explanations, and those phenomena listed above are investigated with the aim to unravel the causal mechanisms or describe the dynamics that characterise them as establishing and pursuing goals. For example, what is relevant when studying a phenomenon identified as homeostatic, such as for example the maintenance of body temperature, is to understand how different subsystems of a living organism produce coordinated physiological reactions that result in the maintenance of certain conditions (like temperature) in a way that is necessary for the viability of the organism at a given time (Cannon, 1929; Hagen, 2021).

Theoretical and philosophical accounts of teleology respond to the need of biology to capture the distinctive purposeful dimensions of these notions and phenomena. Specifically, teleology accounts for goals by explaining the existence of a phenomenon, a system, a component or a trait by reference to the purpose they serve. Teleological explanations aim to explain the presence of a something in terms of what it does. Different perspectives have been adopted to naturalise biological teleology or to take teleology into consideration while explaining biological phenomena. A first coarse-grained distinction can be made between perspectives focused on evolution and on current systems. Different accounts can then differ in terms of the strategies deployed to account for biological purposiveness — e.g. the relevant systems involved and causal regimes grounding purposes— or for the use they make of the concept.

Evolutionary accounts of teleology (see for example Millikan, 1989; Neander, 1991) take lineages as the relevant systems, and natural selection as the causal regime that grounds goals by establishing a causal dependence between the existence of a system (or part) and its purpose. In evolutionary accounts, selection allows to consider the history of organisms as teleological, insofar as the existence of a type of trait can be explained by some of its specific effects or consequences, that have contributed to the adaptation and survival of the ancestors of the organism to which the trait belongs. The causal link between activity and existence is realised historically, across generations. Criticism have been moved to this strategy by pointing out that it presupposes the existence of individual living systems that interact with the environment, keep themselves viable and reproduce, thus contributing to the maintenance of the lineage. These systems already operate teleologically (Christensen & Bickhard, 2002; Mossio & Bich, 2017; Gambarotto, 2023). According to this criticism, evolutionary accounts would presuppose a teleological regime already at work at the organismal level.

Non-evolutionary accounts of biological teleology focus on this organismal level. They include the organisational account and the so-called 'behavioural approaches' (Nahas & Sachs, 2023). Behavioural approaches assume teleology at the outset, and they use it to describe how organisms interact with their environments. One example is represented by the enactive approach (see for example Gambarotto & Mossio, 2024), which treats organisms as purposeful systems by assuming they have a teleological organisation and focuses on describing their behaviours. Another example is constituted by Denis Walsh's approach, which also assumes that organisms have goals and act teleologically. Based on this assumption, it addresses evolutionary processes in terms of goal-directed agents (Walsh, 2015). While their foci differ, these approaches, like evolutionary accounts, also presuppose a teleological regime realised in individual living systems. However, their objective is different: they do not aim to naturalise teleology, but they employ the notion to explain and naturalise other phenomena.

The organisational approach shares with the other non-evolutionary approaches the focus on living systems as the grounds for teleology. However, like evolutionary approaches, it aims to naturalise the notion. To do so it employs a similar strategy, which aims to identify a causal circularity which relates teleology to the contribution to the conditions of existence of a system. To ground purposes, evolutionary and organisational approaches both look for a circular causal regime such that the conditions of existence of a biological entity can be said to depend on its own effects. While sharing a general strategy, the organisational account differs from evolutionary accounts with respect to the causal regime responsible for the realisation of this causal circularity—that is, organisation rather than natural selection—and to the system considered relevant—a living system rather than a lineage. It looks at the current organisation of a biological system, instead of its evolutionary history, thus developing an account that can be considered complementary to evolutionary ones.

The organisational approach focuses precisely on how current individual organisms maintain themselves and survive in their environment. It investigates the relationship between conditions of existence of a biological entity and its own activity. It does so by establishing a connection between organisation and teleology through the concept of self-determination. The starting point is the idea, developed in the autonomy tradition, that living organisms are organised in such a way that they produce their own components, they run their internal processes, respond to perturbations, and maintain themselves without being completely driven by external factors (Piaget, 1967; Rosen, 1972; Maturana & Varela, 1980). This core idea has been recently given a more precise characterisation in causal terms by means of the notion of closure of constraints, which constitutes the theoretical basis for the organisational account of teleology. I will not delve into the details of the notion of closure of constraints, as various aspects have already been thoroughly discussed by Mossio et al. (2013), Moreno and Mossio (2015), and Montévil and Mossio (2015). Instead, I will summarise the main ideas necessary to understand how closure of constraints has been employed to ground teleology.

According to the organisational framework, a constraint C is a material structure that harnesses a process P, making it possible. C exerts a distinctive causal power on P, limiting the range of possible outcomes (degrees of freedom) of P. Moreover, at the time scale in which P occurs, C is locally unaffected by it: the constraint is not part of the process and is stable during it. An example of constraint is an enzyme, which catalyses a reaction, thus making it possible, or a pipe harnessing the flux of water, thus canalising it in a given direction. In virtue of these properties, constraints can be considered as conditions of existence of a process. Constraints are necessary for a process to take place and achieve a specific outcome. The distinctive character of biological systems is that they are capable of generating from within some of the (internal) constraints that make their internal processes possible, and that are therefore necessary for their own functioning (Moreno & Mossio, 2015; Montévil & Mossio, 2015). In the biological case, by acting on those processes responsible for the production of other constraints, constraints are conditions of existence for the other constraints in the systems. This is the core of the idea of closure of constraints: for each constraint C′ acting on a process in the system, at least one of the conditions for its existence (production and maintenance) are dependent on the activity of another constrain C″ in the system, which maintenance and existence directly or indirectly (through other constraints, for example C‴) depends, in turn, on C′.

This set of constraints (C′, C″, C‴ … C^n) realises a distinctive circular causal regime, which achieves self-maintenance through self-production: a network of mutually dependent constraints that (1) are continuously constructed by the organism; (2) are mutually dependent for their production and maintenance, and (3) collectively contribute to the maintenance of the system by making production and behavioural processes possible. In this causal regime each constraint contributes to the maintenance of the conditions under which the whole network can exist. In turn, the conditions of existence of the constraints are mutually determined within and by the organisation itself.

As argued in Mossio and Bich (2017), an organisation realising closure of constraints is teleological because it determines itself through self-constraint. Specifically, this means that the effects of its own activity contribute to establishing and maintaining its own conditions of existence and those of its parts (its internal constraints). On this view, a biological system is what it does: it is cause and effect of itself. The existence of the system and its parts depends on their effects. The circularity between existence and activity allows conceiving of an individual biological organisation as an intrinsically teleological causal regime: its own activity is fundamentally oriented towards an end, which coincides with its own maintenance. The intrinsic goal (*telos*) of a living system is identified with the maintenance of the conditions of existence on which the organisation exerts a causal influence.

This approach is considered Kantian, in the sense that is compatible with or resembles aspects of the approach to teleology pursued by Kant in his *Critique of Judgement* (Kant, 1790/1987). It characterises purposes in a context in which the components exist for the whole system they generate and the whole exists for the components it produces and maintains. Kauffman (2000) and Weber and Varela (2002) are among the first to have underlined this Kantian legacy linking teleology with organisation. The epistemological or theoretical status of Kantian's teleology and its implications, however, are matter of controversy (Zammito, 2006). Gambarotto and Nahas (2022), have recently distinguished two different types of Kantian approaches to biological teleology: heuristic and naturalistic. The first considers Kant's teleology as a heuristic tool for producing explanations of biological phenomena. The organisational account of teleology would belong to the second type, more theoretically oriented, which looks for a new way to think about biological systems that should be developed by naturalising teleology and turning it into a legitimate scientific concept.

Compared to other attempts to naturalise teleology, the organisational account has the advantage that it takes biological purposiveness not just as an *explanans* but first and foremost as an *explanandum*, and it characterises it by focusing on the capability of biological system to maintain themselves. It attempts to flesh out at the organismal level the very teleological regime of self-maintenance that is instead presupposed by the evolutionary and behavioural approaches. Another feature and virtue of this organism-centred view consists in its comprehensive focus on the system a whole, which is the source of the *telos*: "teleology is not restricted to biological functions but understood as the intrinsic goal-directedness of whole organisms" (Nahas & Sachs, 2023, p. 2). This is something that sets this account apart from evolutionary ones, which focus on traits only. Moreover, it is able to provide principled distinctions between closely related notions. One is the distinction between *intrinsic* and *extrinsic purposiveness*. There is intrinsic purposiveness when the circular relation between existence and activity takes places within the considered entity or system, and the goals play a role within the system itself. It is the case of biological systems. There is extrinsic purposiveness, when the *telos* of a system is distinct from its conditions of existence. That is the case of artefacts, which have goals for a designer or for a user. A second distinction is between teleology and *directionality*. Teleology depends on a circularity between existence and activity, between causes and effects, grounded in self-determination. Directionality, instead, consists in converging to a final state. According to this framework, such a state is not a proper goal. It is only an effect of a given causal regime but does not play a causal role in it.

3 | THE LIMITS OF THE ACCOUNT

The organisational account is a minimalist account of teleology. It aims to identify the most basic causal regime capable of grounding purposes. Purposes are characterised as contributions to the maintenance of the system, and they are expressed in terms of self-production realised through closure. On this view, the system pursues its goal—that is, maintaining itself—by establishing the conditions of existence for the processes of production, maintenance and replacement of the very components responsible for carrying out these processes. Purposiveness depends on the fact that the parts do what they do, thus maintaining the system and themselves. If they did not do that, neither they nor the system would exist. Either self-determination is achieved, and a teleological regime is realised, or not.

This account exhibits two main issues, which both depend on its grounding teleology in the basic notion of closure considered as self-maintenance through self-production. The first issue is that the account may be too wide. The boundaries of biological teleology are not precisely defined through the notion of self-constraint. At the upper boundary, it is left unclear whether ecological systems would count as teleological. Let us suppose that some ecological systems realise a form of closure of constraints. It would follow that they are teleological. However, intuitively, there would be a deep difference in the way we would think of teleology in the case of an organism or an ecosystem. While we would easily ascribe to organisms the capability to pursue goals and to actively do so, we would not as easily attribute the same capability to ecosystems. The basic account of organisational teleology does not seem to capture this difference. This may depend on the fact that it does not focus on how goals are achieved or pursued but only on how they are established through the production of constraints.

A bigger problem regarding the extension of teleology, however, emerges when trying to establish a lower boundary. The account developed in Mossio and Bich (2017) does not provide a clear principled response to whether infra-biological systems such as dissipative structures are teleological. Dissipative structures are out of equilibrium systems that under appropriate (external) boundary conditions spontaneously emerge and realise stable patterns (Nicolis & Prigogine, 1977). An example is Benard's convection cells, ordered dynamical structures that emerge in a thin layer of water when a given gradient of temperature is established between lower and upper surface of the liquid. Other examples are whirlpools and whirlwinds that are formed in bodies of water or in the air. According to some interpretations, these patterns constrain the movement of the particles that make them up, thus contributing to maintaining adequate conditions for their dynamics (Bickhard, 2000; Bishop, 2008). Characterised in this way, these systems would be instances of self-determination as self-constraint, and therefore teleological, even if just one constraint would be involved. However, there are good reasons to consider they are not. The pattern can be described as an attractor. It does not play an operational role in the explanation of these phenomena and, as any other attractor, it can be considered as an effect, not a cause of the phenomenon (Bich, 2012). Moreover, dissipative structures, including the phenomenon of generation of the pattern, are totally dependent on external conditions. However, whether or not they achieve self-determination through self-constraint in the end remains a matter to be resolved empirically, and Mossio and Bich (2017) leave the answer somehow open. There are not enough principled arguments to trace a precise distinction and to establish a lower limit for intrinsic teleology. This, I will argue in the next section, depends on the fact that the notion of closure may be too basic, and insufficient, if employed alone, to fully characterise biological teleology.

The main issue faced by the organisational framework concerns how it accounts for purposeful phenomena. Teleology is characterised in terms of the contribution to establishing and maintaining the conditions of existence of a biological system. Goals are established by means of the production of components. On this view, a system "does what is does". This idea, however important to ground a basic *telos*, does not account for the possibility of different ways to pursue and realise goals based on different alternative ways to realise self-maintenance. Yet this is what most biological phenomena are about. Maintaining an organism constantly involves decisions, i.e. physiological and behavioural changes made on the basis of internal and external conditions (Bechtel & Bich, 2021). This is even more evident in development, where radical structural and functional changes occur (Bich & Skillings, 2023), or in agential behaviour, which requires sensing the features of the environment to generate different viable behaviours accordingly (Moreno, 2018). Even metabolism and biosynthetic processes take place based on decisions: e.g. when to start synthetising a protein, where to transport it, how to modify its conformation and modulate its activity. These decisions result in different but all necessary ways to pursue self-maintenance, the *telos* of the system. Leaving all this variety of goal-oriented activities implicit can greatly limit the possible application of the organisational framework to real biological cases. A further aspect to consider is that without taking into account these organismal adaptive capabilities and how they are realised, it is not conceivable to try and establish bridges between the organisational account and evolutionary ones.

Developing a minimalist account has been useful to provide a basic but solid philosophical and theoretical grounding for the notion of teleology, a minimal common starting point from which to consider a system as purposeful. However, the minimal account needs to be employed as a stepstone to build a richer view that can account for the fundamental features of biological systems and be applied to a wider range of phenomena.

In this section I discussed the limits of the organisational account of teleology. In the next sections I will revise its theoretical assumptions with the aim to solve these issues and provide a richer framework that can be better account for biological purposeful phenomena and be applied to specific biological cases.

4 | QUESTIONING THE THEORETICAL FOUNDATIONS

The limits of the organisational account of teleology consist in the fact that it is too permissive in terms of systems that can realise it, but at the same time too narrow in terms of phenomena it can explain. I will argue that such limits coincide with the limits of the notion of closure that underlies this teleological framework. Both closure and the associated notion of teleology are too minimal. Closure has the virtue of accounting for a fundamental feature of living systems, the capability to produce and maintain components (and the system itself) by establishing the conditions of existence for internal processes. However, taken alone it is insufficient to explain what living systems do and how they maintain themselves, that is, some of the distinctive features of biological organisations.

A first step towards improving the organisational account of teleology is to focus on its theoretical foundations: what is needed is a better account of biological organisation. The notion of closure of constraints have been focusing on the mutual dependence between functional components of biological systems (characterised as constraints) for their production and repair, considered as the core foundation of the theoretical framework (Montévil & Mossio, 2015). Developing a rigorous account of the type of relations underlying self-production has indubitably been a major achievement and an important foundational step in developing the organisational framework. However, this research line has tended to assume that what characterises the core organisation of biological systems is just the causal regime of production of components (closure) which achieves self-maintenance based on generative relationships alone. This causal regime has been understood as inherently stable, the activity of its parts characterised by regularity unless perturbed, and environmental perturbations compensated for by building new parts to replace those damaged (Mossio et al., 2016).

Despite its virtues, by being so minimal this perspective is partial and biologically inaccurate: providing a clear conceptual characterisation of self-production has come at the price of abstracting away other relations that are essential to understand biological organisation. Biological systems are not just alive, but need to deploy a variety of activities that allow them to keep living. They do not just replace and repair their parts. They modulate these activities and more generally modify themselves and what they (and their parts) do based on their internal physiological state and environmental conditions. As a matter of fact, the basic constraints involved in a regime of closure are not always functioning, or functioning whenever their substrates and energy are available. Their activities are constantly controlled: inhibited, activated, modulated (Bich & Bechtel, 2022b). Let us think of some basic biological activities. The production of ATP from glucose is not carried out constantly, but only when its level is low, and energy is needed by the cell. Cells do not divide continuously, but they engage in division only at some given moments. More fundamentally, even a basic and fundamental activity such as protein synthesis, responsible for the production of those constraints (such as enzymes) participating in the core regime of closure, is not carried out all the time and for all proteins. It is inhibited or activated based on the needs of the cell. Just as a cell cannot carry out all possible activities continuously and simultaneously, it does not synthesise all its possible proteins at the same time and all the time.

These examples show that to maintain itself, an organism continuously modulates and coordinates the activities of its basic constraints. It needs to do so in such a way that they can collectively realise a viable regime of closure. While closure emphasises the mutual dependence between components for their production, it does not account for how their activities are also mutually dependent and result in the integration of components within a system that maintains itself as a cohesive whole. In living systems, different parts or groups of parts provide different and specific contributions to the functioning and maintenance of the system. Harbouring components capable of playing different tasks such as catalysis, transport, compartmentalisation, signalling, DNA transcription, translation, protein synthesis, etc. is a fundamental requirement for a system to build and maintain itself. However, only those activities needed in the current situation need to be carried out. Moreover, some parts or subsystems may work differently and with different requirements, which are not always compatible, or specific activities need to be carried out only when others have already been completed or some specific conditions are met. Therefore, besides producing all these components to ensure their presence within the system, a cohesive integration between these different tasks, including production, is only achieved when those different activities are orchestrated so that they collectively contribute to the maintenance of the system.

Another aspect that is important to emphasise in this respect is that while closure emphasises stability and continuity (Mossio et al., 2016), living organisms constantly need to change (Bich & Bechtel, 2022b; see also Piaget, 1967 and Di Paolo, 2005). To maintain viability, they need to modify the activities of their components to coordinate different physiological tasks, but also to responds adaptively to environmental variations. They need to orchestrate the activities of their parts to achieve at the same time integration and versatility. All this requires making decisions (Bechtel & Bich, 2021): modifying what living systems do on the basis of internal and external conditions.

In a nutshell, what is required to achieve so, in addition to closure, is regulatory control (Bich et al., 2016). As argued by biochemists Cornish-Bowden & Cardenas (2020, 1), even if we just focus on metabolism, the idea of closure is insufficient to make sense of biological systems as it fails "to take account of mechanisms of metabolic regulation, which we regard as crucial if an organism is to avoid collapsing into a mass of unregulated reactions." (see also Fell, 1997).

Regulatory control implies an asymmetric interaction: a controller acts upon a controlled process, component, or subsystem. For a biological system to control itself—modifying its internal processes and the activities of its components based on internal and external conditions—it needs the ability to employ specialised control components. Within the organisational framework, this requires introducing a special type of constraint. Most constraints are realised by structures which statically reduce the degrees of freedom of the process they canalise. It is the case of the classic examples of constraints mentioned in the previous sections such as a pipe or a simple enzyme. This may be sufficient to enable a process. Control, however, implies something more, that is, the capability of modulating and coordinating the activities of other constraints towards a certain goal (behaviour or state) based on circumstances. As I will discuss in detail in the next section, this is a fundamental purposive activity carried out by living systems, one that is not captured in the basic notion of closure.

Control requires dynamic constraints that can actively select between different possible outcomes or activities available in the process or component on which it operates and modifies (see Pattee, 1972). This means that besides the basic constraints involved in the regime of closure, a biological organism needs to employ second order constraints that are sensitive to the state of the system or the environment, and that modulate the activity other constraints accordingly (Bich et al., 2016; see also Winning & Bechtel, 2018). They do so in such a way as to contribute to the maintenance of the system: they are regulatory. In sum, regulatory control constraints are dynamic constraints. They do not operate on production or repair processes but on other constraints. A simple example is a kinase enzyme, that enables or inhibits the activity of metabolic enzymes in the presence of signal molecules or specific conditions in its surroundings.

In this section I have argued that in a biological organisation there cannot be closure without regulation. Together, these two organisational features account for how different components in biological systems come together into a cohesive unit, where they are mutually dependent for their production, maintenance, and activity. In the next section I will discuss how including regulation can help to reframe the organisational account of teleology and to possibly overcome its limits.

5 | REFREAMING THE ACCOUNT BY FOCUSING ON REGULATORY CONTROL

Closure of constraints focuses on one fundamental feature of living systems, self-production, and emphasises the mutual dependence between parts and between parts and the system they realise. However, taken alone it does not explain what living systems do, how they do it, and how they maintain themselves as a result. Introducing regulatory control in the theoretical framework explains how a regime of closure can actually work—as the activity of every biological constraint is highly controlled—and also how a living system selects between different modes of operations and carries out the activities necessary to maintain itself. This requires the presence of control constraints with sensory-effector capability, that modify the activity of other constraints in the system on the basis of the internal and external conditions. Moreover, these constraints do not work independently of one another, but their activities are in turn integrated at the system level so that their combination gives rise to specific activities and behaviours (Bich & Bechtel, 2022a, 2022b). The result of the operation of this host of control constraints is regulatory, that is, it contributes to the maintenance of the system.

On this view, in order to keep living biological systems constantly make decisions based on the combined evaluation of their states and properties of the environment (Bechtel & Bich, 2021): what proteins to synthetise and when, how and when to activate or inhibit them; which membrane channels to open or close to let molecules and ions in and out or pump them against gradients; when to move in the environment and in which direction depending on the presence of food and predators. They do not only take independent local decisions. More globally, regulatory control is responsible for setting the agenda for the whole organism. It establishes enduring system-level regimes (agendas) such as feeding, rest, growth, reproduction or the physiological phases related to the night-day cycle, where priority is given to specific sets of activities aimed at realising them. It then selects the components' activities that need to be mobilised and modulated in order to execute such agendas (Bechtel & Bich, 2023).

What happens to organisational teleology when one replaces basic closure with regulated closure as the causal regime responsible for self-maintenance? The framework can now account for the choice between different activities aimed at keeping the system alive and viable, which are invisible from the point of view of closure of constraints. All the activities of the constraints that are part of the organisation are considered as purposeful, but while some constraints just operate under given conditions, others allow the system to take specific actions. Production constraints produce the parts necessary to realise this regime. They just operate when their starting conditions are met, and in so doing they contribute to the maintenance of the system. Control constraints, instead, evaluate alternative modes of operation given the state of the system and the environment, and depending on that evaluation modulate the activity of basic constitutive constraints in such a way that the system as a whole maintains itself.

These are two distinct ways to operate teleologically. In a regime of basic closure (production of components), the effects of the activity of the system are teleological in a minimal sense as they contribute to establishing and maintaining its own conditions of existence. Considering also regulatory control allows one to take into account how organisms not only establish (operation of basic constitutive constraints) but also actively exert a control over the way they contribute to their own conditions of existence (operation of regulatory constraints). Living systems do not only maintain themselves but perform their activities in such a way as to maintain themselves. These are two distinct yet mutually dependent dimensions that need to be captured by an organisational account of teleology.

Recently, others have also proposed grounding teleology in regulation, but they do so in a radically different way (González de Prado & Saborido, 2023). They adopt a more traditional approach to teleology focused on specific traits rather than the system as a whole. They consider the activity of regulatory components individually and independently from the organisation that harbours them. To ground goals in this context, they emphasise the fact that regulation is an activity that involves a selection of the states or operations of the regulated components. They argue that in virtue of this activity, one can consider regulation as teleological in itself, as a special case of those accounts of teleology based on biological selection. The path I take here is different inasmuch as, following the organisational approach, it relies on the identification of a circular causal regime between activities and existence of a system as the ground for goals, and considers regulation in the context of this organised regime.

To understand the different dimensions of organisation and teleology, it may be useful to recall here Hans Jonas' criticism of cybernetics (Jonas, 1953; Mossio & Bich, 2017). Cyberneticians argued that individual homeostatic mechanisms, such as feedback loops, are teleological inasmuch as they compensate for perturbations by maintaining the reference value of a given variable within a certain range (Rosenblueth et al., 1943). On their view, the “goal” of a homeostatic mechanism is precisely defined as the interval within which the mechanism maintains the target variables. Jonas points out that there is a principled difference, not captured by cybernetics, between *serving* a purpose and *having* a purpose. Homeostatic mechanisms, taken in isolation, only serve extrinsic goals, but they do not have goal themselves. They presuppose the existence of an organisation that produces and maintains them, but they do not necessarily realise a circular causal regime in which they contribute to the existence of this very organisation. In a biological system, instead, goals are established within the (biological) system responsible for the existence of the mechanism which, in turn, contributes to the maintenance of the system itself. The organisational framework proposed in Mossio and Bich (2017) and based on closure, accounts for this generative dimension of both *having* goals and *serving* them. The conditions of existence of a biological system, its *telos*, are established (having goals) by the system itself through the operation of the components that realise it. Just by operating, these components also serve the goal of the system.

Regulatory control, defined in the context of a biological self-maintaining organisation, adds a further dimension: actively *pursuing* goals. Saying that regulation implies actively *pursuing a goal* in a regime that establishes and maintains goals, means that living systems are teleological not only because their parts operate and, as an effect, contribute to maintaining the system. They are teleological because they perform their activities when needed and in such a way as to maintain the system. Given how the two ways of thinking about self-maintenance are theoretically intertwined and depend one on the other, in biological systems one cannot separate the fact of having a goal (be purposeful) and pursuing a goal (acting purposefully).

On this view, a teleological regime is not realised or is not solely dependent on whether the components of a system are operating. It can also be realised in different ways depending on the circumstances. Organisms, while maintaining themselves, choose between different available courses of action based on their needs and environmental conditions. Control constraints allow a biological system to evaluate alternative modes of operation given these internal and external conditions, to select between its possible actions, and to take the selected actions to maintain itself. Depending on that evaluation, they modulate the activity of basic productive constraints in such a way that the system as a whole maintains itself.

A regulated biological organisation, therefore, does not only establish its own conditions of existence, as described by the notion of closure of constraints. It also operates on how these conditions of existence are realised. The main difference between basic and regulated closure is that the first includes activities that have the effect of maintaining the system, the second accounts for how the system modulates these activities so that they contribute to maintain the system. Including regulation enriches the organisational account of teleology by treating a living organism not only as being teleological but also as acting teleologically.

Can this account address the issued faced by the organisational account of teleology, discussed in section 3? Regarding the problem of the boundaries of biological teleology, if one adopts this perspective, it follows directly that infra-biological systems such as dissipative structures are not teleological. Having an organisation requires "internal division of labor whereby different components perform different causal roles" (Levy & Bechtel, 2013, p. 243). Dissipative structures have only one constraint. They are not organised. Even if one accepts that they realise or could in principle realise a form of self-constraint, they cannot employ, even in principle, control constraints to regulate their internal dynamics. Therefore, they cannot be considered teleological.

The case of ecosystems is partially different. Ecosystems are organised systems in which different groups of organisms perform different activities, while collectively operating on fluxes of matter and energy. Although there is no agreement (Lean, 2021), Nunes-Neto et al. (2014) argue that they realise a form of closure of constraints, but not regulatory control. Therefore, according to the account of teleology presented here, they are not teleological, or at least not in the biological sense. However, no argument has been provided yet on why they could not realise in principle some form of regulated closure. In this case the answer is still open, and more conceptual work needs to be done.

The main issue faced by the original organisational account of teleology concerns the applicability of the framework to real cases and its capacity to capture the complexity of purposive phenomena in biology. In this regard, the advantage of adopting the reframed organisational account is that it maintains the conceptual precision and virtues of the original one while being able to address different dimensions of purposiveness. It accounts for teleology not only by acknowledging that a biological system is purposeful because it is there, alive. It characterises a system as teleological in terms of how it maintains itself alive. This allows one to consider (1) what conditions are affecting a living system, (2) what types of actions are performed in those specific conditions, (3) how these actions are caused by one or more regulatory constraints, (4) how these constraints affect the operations of more basic productive constraints and (5) how these actions contribute in different ways to the maintenance of the system. Based on this framework, one can analyse specific cases by identifying and evaluating these five elements. For example, in the case of physiological phenomena, purposeful activities are identified in terms of changes in how a system performs its basic operations. These activities are often considered under labels such as 'homeostasis' and 'allostasis' (Hagen, 2021; Ramsay & Woods, 2014). Homeostasis is mostly used in those case in which the coordinated activities of the components of a biological system result in the maintenance of the values of some physiological variable within a certain range. Allostasis is used to describe cases in which to maintain themselves and respond to perturbations biological systems undergo more radical physiological changes that imply modifying the range of variation of these core variables. The framework proposed in this paper provides tools to identify what types of physiological changes are teleological, and to categorise them on the basis of how they are produced and how they affect the maintenance of the system (for some initial work in this direction see Bich et al., 2020; Bich & Bechtel, 2022a; Bich & Skillings, 2023). One can also adopt this framework to study agency as a purposeful phenomenon. This implies analysing behaviours in terms of how a system operates in its environment—on the basis of what decisions and by deploying what mechanisms—, identifying what actions imply actively pursuing goals, and distinguishing them from accidental or side effects.

Moreover, unlike the original one, an account based on regulated closure can open up possible connections with other lines of research that are looking at different dimensions of purposeful phenomena. One example is new research focused on mistake-making in biological systems. Hill, Oderberg, Gibbins, & Bojak (2022, pp. 4–5), for example, define mistakes as: "physical variations that threaten function, where "physical variations" can be either in the system's environment or the system's structure and "function" is understood as effective action, meaning action that brings about relevant and well-timed change that preserves, protects, or promotes the welfare of an organism …" On their view, function is closely related to regulatory capabilities, and so are mistakes. The original account of organisational teleology cannot account for mistakes because it takes a yes or no approach: either the system is alive and therefore it achieves is intrinsic *telos*, or not. There are no actual threats for this type of system, because there are no possible actions to counteract them, apart from replacing one or more components. Threats can be characterised only a posteriori if the system has failed to maintain itself. The reframed account, instead, offers a richer perspective, which emphasises the fact that living systems can maintain themselves in different ways and they can actively shift between them. This is possible because they make decisions based on what they sense, but it also gives them capacity to respond to threats, as well as the potential to make mistakes and to act in order to correct them.

6 | CONCLUSIONS

The teleological account of teleology considers living systems as intrinsically purposeful. It grounds teleology in self-determination as self-constraints, and it identifies the intrinsic *telos* of biological systems with their maintenance. I have discussed two issues faced by the original formulation of this account: how to draw boundaries for biological teleology, and how to capture the complexity of purposeful phenomena and provide tools to address specific case studies. I have identified the source of these issues in the core notion of closure of constraints employed to ground teleology. I have argued that reframing the account by incorporating the notion of regulatory control in the conceptual foundations can improve the account and overcome its limitations.

The core idea of the updated framework is that biological systems do not just establish their conditions of existence, which coincide with their intrinsic *telos*. By selecting and taking actions to maintain themselves (changing their activities on the basis of state of the system or environment), they also actively exert a control over the way they establish and contribute to their own conditions of existence. They do so by modifying the activity of basic constitutive constraints according to circumstances in such a way as to maintain themselves.

Considering regulatory control allows this framework to account for the fact that living systems are not just teleological, in the sense that have goals, but act teleologically, that is, they actively pursue those goals. To maintain themselves, they make decisions based on evaluation of circumstances and select between different available courses of action. On this view, biological systems can be characterised as teleological because the effects of their own activity contribute to establishing, maintaining and *controlling* their own conditions of existence.

This is a first step. The reframed organisational account of teleology can then be employed to discuss specific cases of purposeful behaviours in physiology and agency, in order to explore the potential and limits of teleological explanations based on organisation.

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CONFLICT OF INTEREST STATEMENT

The author has no conflict of interest to declare.

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