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Outonomy: Fleshing out the Concept of Autonomy Beyond the Individual

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ISSN 2211-4548 ISSN 2211-4556 (electronic)
SpringerBriefs in Philosophy
ISBN 978-3-032-05500-2 ISBN 978-3-032-05501-9 (eBook)
https://doi.org/10.1007/978-3-032-05501-9

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Preface

This book brings together a rich and multifaceted exploration of autonomy in interactions, exploring its dimensions within philosophy of biology and origins of life, philosophy of mind and enactivism, philosophy of medicine, technology, and politics. The chapters span theoretical foundations, the emergence and dynamics of life, the embodied self, and the sociotechnical and ecological dimensions of autonomous systems. Through this structure, the book provides a coherent yet diverse perspective on the new concept of *outonomy*, one aiming to expand new insights and critical engagements across disciplines about how autonomy is also related to the environment and to others.

We are especially grateful to the contributing authors, who were actively involved at every stage of the project. In addition to writing their chapters, they served as reviewers for each other's work, ensuring a robust and constructive peer review process. Their careful feedback and intellectual generosity greatly enhanced the coherence and quality of this volume.

We also benefited from the input of several external reviewers, whose independent evaluations provided valuable perspectives and helped sharpen the contributions further. We warmly thank the following external reviewers: JuanBa Bengoetxea, Alejandro Fabregas-Tejeda, Laura Nuño de la Rosa, Miguel Segundo-Ortin, Laura Mójica, Antonio Casado da Rocha, Mirko Prokop, and Ion Arrieta.

This book is the result of sustained collaboration within an ongoing research network, and we would like to express our deep appreciation to the projects and initiatives that supported it. In particular, we are grateful to the Principal Investigators who have guided and nurtured this work over the years. We especially thank Leonardo Bich for his insights and commitment to the project that made this publication possible.

The resulting collection reflects not only the maturity of current discussions around autonomy and related concepts, but also the openness of this research community to novel approaches and applications. We hope this volume will serve as a valuable resource for scholars across disciplines, and that it will stimulate further inquiry and debate in the years to come.

San Sebastian, Spain

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Acknowledgements

This book started developing as a result of research project Outonomy, PID2019-104576GB-I00 funded by MCIU/AEI/10.13039/501100011033 and continued under project Outagencies, PID2023-147251NB-I00 funded by MCIU/AEI/10.13039/501100011033 and FEDER/UE. Funding for the OA publication of this book was provided by the *IAS-Research group on Life, Mind and Society* funding IT1668-22 from Basque Government.

Contents

Part I Theoretical Insights

Part II The Fabric of Life

Part III The Psychic Self and Its Environment

Part IV Technology, Ecology & Politics

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Part I
Theoretical Insights

Chapter 1
Outonomy, the Very Idea

Xabier E. Barandiaran and Arantza Etxeberria

Abstract The concept of autonomy, as the capacity of a system to govern itself according to its own normativity, is central to modernity. Its theoretical significance spans across various scientific and philosophical fields. Traditionally, however, autonomy has been conceived as arising within the boundaries attributed to the individual in an abstract, internalist and self-sufficient manner. During the last decades, this conception has been challenged at different scales and requires a revision that crosses the boundaries of the individual and takes into account the material embeddedness, open interactivity, and deep interdependency of natural and social phenomena. We propose that autonomous systems are better understood as emerging-from and depending-on different scales of interactivity, collectivity, extensionality, environmentality, and through the lenses of integrativity and sustainability. This updated approach we call *Outonomy*.

Keywords Autonomy · Outonomy · Individuality · Interaction · Integration · Sustainability · Collectivity · Environmentality

1.1 The Concept of Autonomy in the Philosophy of Life, Mind, and Society

The concept of autonomy (*autos* = self, *nomos* = norm) originated in classical Greece and was reborn in modernity, coming to occupy a central place in the conceptual foundations of our societies, human self-understanding, and our comprehension of the living. This notion, often conceptualized as self-determination, refers to the capacity of systems to operate according to their own normativity, in a manner that

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X. E. Barandiaran and A. Etxeberria (eds.), *Outonomy*,
SpringerBriefs in Philosophy, https://doi.org/10.1007/978-3-032-05501-9_1

is not reducible-to nor specified-by its environment or constituent components in isolation. Although it has multiple interpretations across philosophical and scientific disciplines, it has traditionally been associated with the rational, self-sufficient individual, emphasising self-governance and independence in Modern thought.

Nowadays, the concept of autonomy is fundamental to account for the defining character of the living (Moreno and Mossio 2015), its origins (Lauber et al. 2021; Shirt-Ediss et al. 2017), and how organisms maintain themselves as cohesive units through change (Bechtel 2007; Ruiz-Mirazo and Moreno 2012), development (Nuño de la Rosa 2010; Bich and Skillings 2024), and evolution (Cortés-García and Etxeberria Agiriano 2023; Walsh 2015). It also acts as a conceptual anchor for the notions of *function* (Christensen and Bickhard 2002; Mossio et al. 2009), *teleology* (Mossio and Bich 2017) and *agency* (Barandiaran et al. 2009) within biological and cognitive sciences, as well as *normativity* with respect to concepts of health and disease (Etxeberria 2016; García and Barandiaran 2025). In *metaphysics* autonomy is key to categorize actions in contrast to mere events (Buss 2014), to naturalize free-will (Newsome 2009; Walter 2001), or to characterize emergence and downward causation in metabolic and neurobehavioural domains (Ruiz-Mirazo and Moreno 1998; Thompson and Varela 2001).

Following the Kantian legacy in *ethics*, autonomy is an analytical and regulative concept strongly associated with the values of freedom (Mele 1995) and responsibility (MacKenzie and Stoljar 2000). In social and *political theory,* autonomy addresses the notion of political subject (Hardt and Negri 2005), the identity of different social systems (Luhmann and Knodt 1996), the collective dimension of emancipation (Zibechi 2007), or the creative and democratic power of the social (Castoriadis 1991; Escobar 2018).

These myriad approaches rarely share the exact same concept of autonomy. But two points are worth making. First, there is a continuous circulation of sources of inspiration, conceptual pollination, and methodological exchanges among all these fields: from biological autonomy to political autonomy (Castoriadis and Varela 1995; Luhmann and Knodt 1996), from biological to cognitive autonomy (Di Paolo et al. 2017), from cognitive to moral autonomy (Korsgaard 2009), from ecological to technological autonomy (Escobar 2018). Second, albeit at varying degrees, and not without conflict, many contemporary approaches continue to gravitate around a robust cluster of properties inherited from modernity: the self-sufficient, internalist, and abstract nature of the individual of which autonomy is predicated (Metzinger 2015; Pinker 2021). This conception of the individual is in crisis, and the concept(s) of autonomy that cut across these disciplines and scales need to address it.

1.2 Contemporary Challenges to Autonomy

Recent advances in the biological and social sciences have raised some fundamental challenges to the concepts of individuality and identity, particularly through the increasing acknowledgement of the interconnectedness and mutual dependence of natural and social phenomena. As a result, the boundaries of the system become blurry, porous and difficult to identify; pressing the need for a deeper understanding of the biological and social complexity underlying the interactive, relational dimension of autonomy.

The discovery of complex biological associations (symbionts, holobionts, colonies) compels us to reconsider the notion of organism and of individuality (Gilbert et al. 2012, p. 201; Haraway 2016). In cognitive science, the rise of dynamicist, embodied and anti-representationalist approaches (Chemero 2009), along with the expansion of computationalism to include body and environment (Clark and Chalmers 1998) have reshaped the bounds of the cognitive subject, spreading them to living (Lyon et al. 2021) and non-living entities (Hayles 2017).

In the moral dimension, feminist philosophers have rejected (Code 1987), or called for a revision (MacKenzie and Stoljar 2000) of, the individualistic and internalist character of modernity's conception of (masculine) autonomy. They argue that autonomy is "constituted, in large part, by the external, social relations people find themselves in" (Oshana 1998, p. 81), rather than being intrinsic to the rationally self-sufficient individual (Urdangarin and Umerez 2026, this volume). The category of identity in social sciences has also been questioned (Brubaker and Cooper 2000). Similarly, identifying genuine forms of collective autonomous agency remains difficult (Carter et al. 2018), which undermines its application to social ensembles.

Alongside the relative dissolution of the subject,[1] the role of natural and artificial scaffolding in the viability, development, and evolution of autonomous systems has gained recognition (Caporael et al. 2013). The environment is no longer seen as passive but as a complex, dynamic milieu that relationally sustains autonomy (Etxeberria 2026, this volume). Beyond epistemic challenges, contemporary sociotechnical environments jeopardize human and living autonomy. Threats to democratic self-governance and collective agency (Steinhoff 2021; Zuboff 2019) posed by the rising domination of technology and capital which have grown beyond human control (Winner 1978), epitomized by so-called Artificial Intelligence. Similarly, Stengers' "intrusion of Gaia" (2017) highlights how anthropogenic perturbations of the Earth System destabilize the material conditions necessary for the autonomous continuity and reproduction of human societies (Lenton et al. 2020).

* * *

It might be tempting to put into question the very concept of autonomy altogether. But next to these obstacles, we also find new opportunities, theoretical trends and pressing societal and philosophical challenges calling for an updated version of this notion. On the one hand, understanding life, mind, and society beyond the limitations

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[1] See, for example, the post-structuralist critique of the subject in the works of Foucault and Derrida, feminist approaches in Butler and Fraser, the moral philosophy of Korsgaard and MacIntyre, biocognitive theories in Canguilhem and Damasio, phenomenological perspectives in Merleau-Ponty and followers, and posthumanist thought in Braidotti. These thinkers collectively challenge traditional notions of the autonomous subject by emphasizing relational, social, and embodied dimensions of agency.

of molecular, genetic, neural, computational or economic reductionism is crucial, especially as personal, collective, and social-ecological challenges demand respect for autonomy in an increasingly hostile context. At the same time, new capacities for addressing those challenges are emerging through the growing availability of digital data, advances in simulation and modelling techniques, and a philosophical shift toward processual, relational, and materialist understandings of life and cognition. Those help transcend traditional dichotomies and develop conceptual resources to support new accounts of autonomy.

In fact, a family of theoretical approaches is well suited to meet the demands of these challenges and opportunities: organicist (Etxeberria and Umerez 2006; Nicholson and Gawne 2015), organizational (Bich 2024; Moreno and Mossio 2015), and enactive (Barandiaran 2017; Stewart et al. 2010; Varela et al. 1991) theories have advanced non-reductive biological, cognitive and social sciences. They share a common tradition in theoretical biology and the naturalizing project it affords. Autonomy is here developed in terms of emergent self-organization, operational closure between interdependent and mutually enabling processes, and the capacity of living systems to regulate themselves both internally and through their environments.

This understanding is linked to the Aristotelian roots of organicism, Spinoza's concept of *conatus*, and Kant's understanding of organisms as self-organized, which underlies German idealism and *Naturphilosophie*. It continued later in a scientific context, as seen in the work of Claude Bernard, Walter B. Cannon, and Kurt Goldstein. Cybernetics and Systems theory paved the way to reintroduce the concepts of *autopoiesis* and autonomy in bio-cognitive sciences (Varela 1979) and their artificial spinoffs: A Life and AI (Boden 1996). From a thermodynamic perspective, Kauffman (2000) characterised autonomy as closure sustaining *work-constraint cycles*. Margulis' symbiogenesis came to fill an important gap within this tradition: that autonomy can be compatible with collaborative relationships and interdependent ontologies. This latter framework is close to what we refer to here as *outonomy*. Aiming to move beyond purely idealized, rationalist views of autonomy, scientific approaches have consistently sought to naturalize the concept by explaining autonomous organization in biological terms—despite Kant's well-known skepticism (Weber and Varela 2002). Together, organismic, organizational, and enactive approaches contribute to a unified vision of autonomy as a dynamic, relational process that is context-dependent and continuously shaped by interactions with the environment. This emerging vision holds promise for advancing also in social, technological and ecological domains.

1.3 Outonomy and Its Properties

Departing from the legacy of modern individualistic views of autonomy, we introduce and elaborate an renewed approach by the term *Outonomy*, after the language game of "out", to break the self-referential appeal of the "autos" (self). In this book, we present outonomy as a further elaboration of the organismic, organizational and enactive conceptions of autonomy in life, mind, and society. This framework highlights six key properties. Four of them involve expanding beyond individual boundaries towards the environment in the enabling and constitution of autonomy.

1. ***Interactivity****: Autonomy results, not only from internal processes, but also from interactions with the environment and other organisms.* The interactions across membrane, skin, skull, or border that differentiate the individual from its environment are not just resource consumption but active forms of constitution (Etxeberria et al. 2021). Breathing and touching are not simply means to extract oxygen and information from the environment to be internally deployed to produce the individual just by itself, but forms of interaction through which the autonomy of the individual is constituted. Moreover, complex sensorimotor systems also emerge as autonomous processes themselves, further enabling an open interactive dimension extending beyond the individual into the world (Di Paolo et al. 2017; see also Virenque 2026, this volume). Even typically internalist notions, like pain or menstrual health, are ultimately open to social and environmental interactions (see Martínez-Quintero and Rodriguez-Muguruza 2025; Monterde Fuertes 2026, this volume). Autonomy, in this sense, includes specific qualitative forms of interaction. We shall elaborate them next.
2. ***Collectivity****: All forms of autonomy are doubly enabled and restricted by interactions with other agents, forming various assemblages, and opening-up to higher-level autonomous organizations.* From the very origins of life (see Ruiz-Mirazo et al. 2026 this volume) the individual's autonomy is interwoven with that of others. This relational character is particularly evident in inter-organismal reproductive processes (Cortés-García 2026, this volume; Etxeberria et al. 2023), as well as for conceiving the moral and political autonomy of the subject as relational and interdependent (see Urdangarin and Umerez 2026 this volume).
3. ***Extensionality****: Autonomy often (if not always) extends beyond the individual into sedimented structures that are the result of recurrent interactions and those of other autonomous systems.* Technologies and institutions are the most familiar forms of extensionality in humans, but many, if not all, forms of life extend their autonomous processes into their environments. From biofilms in bacteria, to stigmergic structures in insect colonies, or nests in birds, autonomous systems build their environments, organizing the inorganic to extend their autonomy beyond themselves. In some cases, these extensions are so wide and complex, that their increasing autonomy or automaticity hinders that of its creators (see Calleja-López et al. 2026, this volume). In all cases such extensions define relations of co-dependence that produce normative conflicts that challenge the autonomy of the individual in various ways, from oppression (Maiese 2026, this volume) to mental health (García 2026, this volume).
4. ***Environmentality***: *Every autonomous system depends on a larger environment that in turn actively sustains its activities, assemblages and extensions, and which, to a large extent, is constructed by those or other interdependent autonomous systems.* The scale of environmentality situates autonomy within its ecological context, emphasizing the interdependence between agents and their ecosystems.

The environment here is not a passive backdrop but an active and long-term participant in the dynamics of autonomy. As an emergent property of social-ecological systems, autonomy challenges anthropocentric models of governance and advocates for more integrated approaches that account for the interconnectedness of life systems (Cabello et al. 2026, this volume).

The other two properties affect the way of conceiving the self (*autos)* and the normative (*nomos*) aspects of autonomy, across the previous four scales of interaction beyond the individual.

5. ***Integration****: Autonomy manifests through the (degree of) integration of processes that participate in individuation.* The type and degree of this integration serve as good criteria for determining the self or identity of an autonomous system, especially within the messy, fine-grained world of real process interactions. From the outonomy perspective, integration refers to how heterogeneous, interdependent subsystems or components constitute cohesive systems. It involves coordinating the regulation and control of component behaviours such that they contribute to the system´s maintenance (Bich and Bechtel 2026, this volume). It rests to be explored how autonomy could be conceived as a gradual achievement, with integration being a criterion for determining the self or identity of the autonomous system, potentially complementing (or substituting) the concept of closure (whether of constraints, operations, organization, information or otherwise).
6. ***Sustainability****: The normative matrix that characterizes autonomous systems incorporates the care for the sustainability of what is beyond the individual.* Care is understood as the activity that sustains bodies, communities, and environments through a web of life-supporting practices (Puig de la Bellacasa 2017). Autonomy is here reframed to incorporate the inherent precariousness of systems at relational scales that not only support but also demand and implicate individuals and collectivities across multiple levels. This vulnerability takes diverse forms, as considered throughout this volume, ranging from the prebiotic, cellular and organismal scales to human, social and techno-ecological domains.

Acknowledgements XEB and AE acknowledge IAS-Research group funding IT1668-22 from Basque Government, grants PID2019-104576GB-I00 for project Outonomy and PID2023-147251NB-I00 for Outagencies funded by MCIU/AEI/10.13039/501100011033 and FEDER/UE.

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Chapter 2
Intrinsic Purposiveness and Autonomy in Interaction

Louis Virenque

Abstract Autonomy Theory characterizes agency as a subset of functions of an autonomous entity that controls the interactions of the living being with its environment so as to maintain its organization, considered as its intrinsic purpose. Yet, this understanding of agency faces a major philosophical and theoretical problem: there seems to be many purposive interactive behaviors that do not directly contribute to survival, or even run contrary to it, such as playing or smoking a cigarette. The challenge, therefore, is to elucidate these more complex interactive capacities within the framework of the Autonomy Theory. In this chapter, I explore three key hypotheses to address this challenge: first, the idea that such behaviors might respond to underlying biological "needs"; second, the idea that, as emphasized by the enactivist perspective, these behaviors are embedded in a sensorimotor level of organization; and third the idea that these behaviors relate to a social level of closure.

Keywords Autonomy · Intrinsic purposiveness · Agency · Self-determination

2.1 Introduction

In recent years, several scholars have contributed to reviving the concept of *autonomy*, initially introduced by Francisco Varela (1979) to describe the distinctive organization of living systems (Barandiaran and Moreno 2008; Moreno and Etxeberria 2005; Ruiz-Mirazo and Moreno 2004). Autonomy means "self-law" and designates, when applied to the Life Sciences, the particular capability of living systems to self-determine, by realizing a network of reciprocal productive relations among their constituents (the so-called *autopoiesis*). Some proponents of Autonomy Theory (hereafter AT) have refined the original concept by emphasizing that autonomy encapsulates three fundamental concepts, which are: organizational *closure* of constraints,

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X. E. Barandiaran and A. Etxeberria (eds.), *Outonomy*,
SpringerBriefs in Philosophy, https://doi.org/10.1007/978-3-032-05501-9_2

agency, and *regulation* (see Moreno and Mossio 2015, for a synthesis). In this framework, on which I rely here, a living autonomous system is a self-sustaining network of constraints that controls the thermodynamic flow and, thereby, determines by itself its metabolic organization.[1] Philosophically, living autonomous systems can be said to realize intrinsic purposiveness, insofar as the effects of their activity contribute to determining and maintaining their own conditions of existence (Mossio and Bich 2017).

As we shall see, however, this conception of autonomy and purposiveness leads to a dilemma: either any behavior which is deemed purposive can be shown to contribute to self-determination (and then be functional); or non-functional behaviors (e.g., playing or smoking) should not be considered purposive (which would be strongly counter-intuitive). This philosophical dilemma highlights a theoretical problem for AT, when it comes to account for a whole range of behaviors, which do not appear to contribute to the autonomy of the living system.

2.2 Non-Functional Behaviors or Fulfillment of Needs?

A living organism is a dissipative system. While maintaining this constant flow, the system retains its own individuality. A cell, for example, conserves its identity through operations such as the sodium–potassium pump, which actively transports sodium ions out and potassium ions into its membrane, maintaining electrochemical gradients. Despite the perpetual turnover of ions and other components, the cell maintains its identity by performing work (Kauffman 2000). The concept of "*closure of constraints*" captures this idea of self-individuation through self-determination.

A constraint is an entity that channels or limits the activity of other entities, such as the chemical bond for atoms, an inclined plane for a ball, the skeleton for an organism, etc. A closure of constraints characterizes the relationship of mutual determination of a network of constraints, each channeling physico-chemical processes to perform a functional work (see Montévil and Mossio 2015 for a detailed discussion). Some advocates of AT claim that closure of constraints achieves intrinsic normativity and purposiveness. Indeed, the effects of the activities of constraints achieve one overarching goal: the determination of the system's conditions of existence, that are set (at least in part) by the system itself (Barandiaran and Moreno 2008; Mossio and Bich 2017). This causal regime (i.e., intrinsically purposive organization) also provides a natural basis for functional explanations. In fact, in AT, each constraint performs a specific function insofar as it both depends on and enables the activity of other constraints (Mossio et al. 2009; Moreno and Mossio 2015). However, as we shall see, this theoretical framework can face challenges, particularly in relation to agency.

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[1] By 'metabolic organization' I mean the set of functions that maintains an agent as a biological individual far from thermodynamic equilibrium.

According to one version of AT that I follow here,[2] agency is defined in its *minimal* meaning as a subset of interactive functions, i.e. constraints that are functionally exerted on the system's environment. In fact, two nested kinds of functions are part of the closure: constitutive and interactive ones. While the effects of the former take place inside the closure, the effects of the latter operate outside the whole system, on its environment. As a subset of interactive functions (or interactive constraints), agency must be directed toward the self-determination of the system (Moreno and Mossio 2015). For example, behaviors like sneezing or coughing are constitutive but not interactive (agential) functions because, although they modify the environment, these modifications do not promote the continued existence of the system (Arnellos and Moreno 2015).

In contrast, the flagellar rotations of a bacterium that propels itself toward a sugar gradient (chemotaxis) modify the relation of the whole system with its environment. This shift in the interaction with the environment is functional since it contributes to the determination of the system's existence (Moreno 2018). Moreover, bacterial chemotaxis, as any realization of agency in living beings, is a case of *adaptive*[3] behavior. The bacterium is an adaptive agent because it not only performs actions but also adapts such actions to new environmental conditions, i.e., by *regulating* its own flagellar movement while approaching a nutrient source. This is why, in AT, adaptive agency entails *regulation.*

According to AT, regulation consists in the modulation of the system's functions (or organization) by a dedicated subsystem (constituted by a set of second-order functions) in response to environmental disturbances (see Barandiaran and Moreno 2008; Bich et al. 2015; Bich and Moreno 2016). The regulatory activity of second-order functions applies both to the constitutive functions of metabolism and to its interactive functions. Thus, for example, lac operon and chemotaxis are two types of regulation, one acting within the system, the other on its boundaries (see Barandiaran 2008; Bich et al. 2015). According to AT, all organisms are adaptive agents in that they continuously adapt to their environment. If they are adapting, it means that they must have some kind of meaningful relation with what they are adapting to. Consequently, for AT, all adaptive agents "make sense" of their environment in order to survive (Weber and Varela 2001).

The challenge for this conception of agency emerges when one attempts to account for behaviors that do not seem *prima facie* oriented toward metabolic organization but are commonly (and intuitively) deemed to be purposive and therefore agential—such as playing, exploring, smoking or even committing suicide. Now, if one understands intrinsic purposiveness in AT's terms, then a philosophical and theoretical dilemma emerges: either any purposive behavior can be shown to be functional according to AT's definition, or one must conclude that non-functional behaviors

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[2] I rely here on Moreno and Mossio (2015), which distinguishes minimal agency from adaptive agency. For partly different but largely converging definitions of agency within AT, see Barandiaran and Moreno (2008) and Barandiaran et al. (2009).

[3] I rely here on Di Paolo (2005)´s work on adaptivity, characterized as the monitoring and regulation of the tendencies of the system with respect to its boundaries of viability (I thank a reviewer for this compact formulation).

should not be considered purposive. Either way, it's a difficult position to argue for. Behind the philosophical issue lies a theoretical problem: regardless of the term employed, how could AT account for non-(obviously) functional behaviors such as smoking or playing, which are important aspects of an organism's interactions with its environment?

The first possible answer to this dilemma requires taking a step back. Indeed, the dilemma presupposes that behaviors such as playing or smoking are non-functional for the individual that produces them. However, it is possible that our understanding is incomplete, insofar as these behaviors might be fulfilling underlying *needs* of the organism and, therefore, be functional. For example, smoking might fulfil some physiological needs by reducing anxiety and enhancing the feeling of concentration, and therefore perform a function, at least at a relatively short time scale and at limited doses. Similarly, in ethology, playing is not defined as being *fully* functional, that is, as contributing to the immediate survival of the system (Burghardt 2005, p. 71). Therefore, one might consider that playing satisfies a comparable need (e.g., releasing energy or having fun), whose fulfillment also contributes to the metabolic organization. Committing suicide is obviously a more complex challenge, as it does not contribute neither to the short-term nor long-term determination. Yet, let us conjecture that even suicide might possibly respond to a certain biological need (e.g., one might feel a 'metabolic need' to eliminate despair, torment, etc.).

Reconceptualizing apparent non-functional behaviors as behaviors fulfilling individual needs, while providing an original answer to the dilemma, would inevitably face several open questions. What kind of objects are 'needs' in AT? What is their relationship to the system's organization if they can, in some cases, threaten or even undermine it? Relatedly, how exactly would the fulfilment of needs be interpreted as a function? Given that AT currently lacks a workable concept of 'need', I will explore in the next section alternative answers, which presuppose that the behaviors in question are *non*-functional with regards to the metabolic organization that produces them.

2.3 Sensorimotor Relations?

In 2017, enactivist theorists Di Paolo, Buhrmann, and Barandiaran (DPBB hereafter) introduced the notion of sensorimotor closure as enabling new relationships between the organism and its environment (Di Paolo et al. 2017). Their approach offers a potential way for AT to address the above dilemma. For DPBB, those behaviors, which are more complex than those related to the system's metabolic organization, pertain to a "sensorimotor organization" grounded in the concept of *habit* (Barandiaran and Di Paolo 2014).

For DPBB, habits are primarily "self-sustaining precarious sensorimotor schemes," (Di Paolo et al. 2017, p. 144), i.e., behaviors that require repetition to be maintained. However, habits are never "enacted" alone, but always as part of a larger whole that the authors call "activities," which are "bundles of habits" (p. 147). For

DPBB, this interconnectivity between sensorimotor patterns (i.e., between habits) achieves a distinct "layer" of closure, i.e., of self-individuation.

In fact, in a sensorimotor closure, each sensorimotor scheme depends on at least one support structure within the network (p. 151). A support structure is a set of variables that are necessarily associated with an event. For instance, as I understand it, in a sensorimotor scheme such as "bottle feeding," suckling, swallowing and breathing are processes that need a support structure in the body (e.g., swallow support, suckle support, breathe support) and in the environment (e.g., milk, bottle, air). Air, milk, swallowing, and sucking are all necessary variables in the bottle-feeding habit. However, this is a single sensorimotor scheme (or habit). When realizing a sensorimotor closure, several schemes and support structures are interdependent (p. 151). For example, the "running" scheme depends on at least one support structure that also supports "bottle-feeding" (e.g., breathing support), just as "bottle-feeding" also depends on at least one support structure of another scheme, such as eating (i.e., swallowing support). Sensorimotor schemes thus depend on each other in their realization (e.g., in the order of an action), and on the support structures that sustain them within a network that is neither in the environment nor in the agent (pp. 151 and 157). Thus, for DPBB sensorimotor closure has no physical boundary (p. 152). The network of sensorimotor schemes then achieves an asymmetrical coupling with the environment understood as everything that influences the enabling relationship between habits; (p. 153). According to the authors, the network is even adaptive, i.e., it can modulate its relationship with its environment to ensure the viability of a scheme or a succession of schemes (e.g., in the succession of schemas for lighting a cigarette, protect the flame from the wind with your hand (pp. 156–157). Finally, sensorimotor schemes are underdetermined by metabolic normativity. They can respond to it and contribute to it, but also have their own norms of viability. The success or failure of a pattern affects the entire network, including the supporting structures that sustain it, by enabling (or disabling) the continuation of an activity (pp. 157–156).

In brief, according to DPBB, just as metabolic/physiological closure achieves agency through self-individuation, asymmetric coupling, and normativity, sensorimotor closure exhibits *sensorimotor agency*, which may help resolve the dilemma regarding explanations for seemingly non-functional behaviors. In fact, it could be argued that behaviors such as playing or smoking are related to the intrinsic purposiveness and normativity *of the sensorimotor organization*, and not to the metabolic organization. Accordingly, playing or smoking would be functions of the sensorimotor closure.

This hypothesis implies at least one intriguing consequence. As DPBB suggests (p. 147), a habit within sensorimotor closure is analogous to an autocatalytic reaction within metabolic closure: just as the latter sustains the metabolic organization, the former appears to uphold sensorimotor closure. If this is the case, then it follows that the function of the smoking scheme (beyond any extrinsic purpose it may have) consists in maintaining the sensorimotor closure to which it is subject. In turn, this means that the fundamental purpose of performing habits is… the preservation of the very network of habits. Habits then appear not only as underdetermined, but (and crucially) as functionally separated from (although dynamically coupled to) metabolic closure. The theoretical move that consists in distinguishing these two closures, each with its own intrinsic purposiveness, may be open to criticism, precisely because it leads to the conclusion that a habit situated in a sensorimotor network would aim at its own maintenance, or the maintenance of habits situated in the same network (e.g., running aimed at running or maintaining other linked schemes such as squatting or jumping). However, it may be argued that this is too restrictive, as behaviors generally seem to be directed towards something extrinsic to themselves: I run to get away from someone, to have fun, to train for a race, etc..... If so, habits should be understood as contributing to another purpose (and then be subject to another closure), be it metabolic, social or of a different kind.[4] In any event, this hypothesis does indicate a way to address the dilemma by positing the existence of different levels of closure. As a matter of fact, such a strategy can be further expanded to consider broader levels of autonomy, beyond sensorimotor closure.

2.4 Social Relations?

The hypothesis that autonomy can emerge at levels beyond the metabolic one exists since the foundational work of Maturana and Varela, who already postulated forms of autonomy at the immune, nervous, and even social level (Maturana and Varela 1980). The challenge, however, consists of specifying the conditions at which the central tenets of AT can be legitimately applied to different levels of description.

Consider again the example of smoking. As Jarvis (2004) or Nichter et al. (2007) suggest, various aspects of addiction, such as its social dimensions, help explain why people smoke. From this perspective, an alternative way to address the intrinsic purposiveness's dilemma is to propose that behaviors like playing or smoking are indeed purposive, because they perform a function within a higher, collective organization, distinct from their own metabolic and sensorimotor closures.

In *Linguistic Bodies* (2018), Di Paolo, Cuffari, and De Jaegher advance a theory of social interactions that can account for norms extending beyond those imposed by the metabolic (and sensorimotor) organization. According to the authors, bodies are not isolated or static entities, but are rather dynamic processes that interact with both their environment and each other (p. 7). These relationships may, on occasion, give rise to social interactions. Such *social interactions* can result in the formation of a new dynamic organization that possesses its own autonomy without threatening the autonomy of the individuals involved. A *social interaction* is defined as the "regulated coupling between at least two autonomous agents where the regulation is aimed at aspects of the coupling itself" (De Jaegher and Di Paolo 2007, p. 493). The encounter of two agents, as sense-makers, modifies their respective sense-making processes and generates an autonomous relational domain that has its own norms, different from

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[4] Mojica (2021) raises a similar issue and offers a solution by developing an account of 'external normativity' emerging from the interaction of individuals.

individuals' ones. The modification of the social domain by the interacting agents gives rise to *social agency*. An illustrative example of social agency is a conversation. In a conversation both regulate their respective relations to the autonomous domain of the interaction in order to maintain the conversation. To illustrate this further, if I wish to continue a conversation, at a social gathering, with someone who smokes, the social interaction with that person may prompt me to accompany them outside for a cigarette, which would explain my behavior—which is detrimental to my health.

The hypothesis that the interaction between two individuals realizes a distinct autonomous domain viz. a different level of normativity (see for instance Mojica 2021) is debatable, especially if one considers, as I do, that this requires showing that such interaction realizes a distinct level of constraints closure. In their analysis, however, Di Paolo et al. (2018) do not limit themselves to social interactions between a few individuals. While these individuals may engage in specific interactions, they can also be embedded in larger social systems that influence them to reproduce certain behaviors (Di Paolo et al. 2018, p. 84, see also Maiese 2025, this issue). Accordingly, smoking might, in fact, be functional for the agent embedded in this larger social system, insofar as such behavior could confer benefits, such as the fact of belonging to a specific social group, facilitating encounters, making friends, etc.

From this perspective, complex behaviors of this kind would occur in relation to a higher-level closure, within which they would serve a "social function" and would be only indirectly related to the survival of the individual agent (as a part of the larger system). The closure of this broader social organization could even possibly generate new "needs" for individual agents (e.g., the "need" to feel different, rebellious, mysterious, and so on) and provide a more sophisticated explanation for the act of smoking. Although there exists a literature on the organization of social systems that converge with AT (see for instance Luhmann 1995) it remains conjectural whether social organizations can adequately be understood in terms of closure of constraints and, if so, whether this concept of closure would need to be adapted when applied to such an object.

The idea of *outonomy* explored in this book (see Barandiaran and Etxeberria 2026, this volume) might be specifically interpreted as referring to this particular mode of agency, by which an individual autonomous agent performs functional behaviors that contribute to the self-determination (and therefore to the intrinsic purposiveness) of an encompassing social organization to which it belongs. In other words, outonomy would refer to the *interplay* between different levels of autonomy, such that individual agents contribute to an encompassing autonomous system which is, in a sense, external to them, "out there".

2.5 Conclusion

In this brief discussion, my goal was to explore how the concept of agency elaborated by AT could account for more complex interactions between living beings and their environment. As mentioned, such behaviors raise a problem insofar as, while being commonly (and intuitively) understood as instances of purposive agency, they do not seem to fulfil AT's requirements. I have outlined the several ways in which AT can solve the dilemma:

- Firstly, through a reinterpretation of seemingly non-functional behaviors as responding to a "need" of an organism;
- Secondly, through DPBB's hypothesis of sensorimotor closure, which involves a distinct individual dimension of purposiveness and therefore of functionality;
- Finally, through the DPCDJ's hypothesis of a social level of organizational closure, which would ground distinct social "needs" and functions.

Each of these hypotheses is as intriguing as it is ambitious. In fact, each of them addresses at least one fundamental aspect of AT, either by reexamining the notion of organizational function or by reassessing the limits of organizational closure. Consequently, behaviors that do not appear to be directly linked to the self-determination of an individual autonomous biological agent are open to different explanations consistent with AT or, more likely, to a combination of them.

Acknowledgements Thanks to Matteo Mossio, Xabier Barandiaran, Arantza Etxeberria, Laura Mojica, and Miguel Segundo Ortin, for insightful comments and criticisms on earlier versions.

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Chapter 3

Autonomy and Heterarchy: Organizing Control in Biological Organisms

Leonardo Bich and William Bechtel

Abstract In order to maintain themselves as systems far from equilibrium with their environment, organisms must control the operation of numerous production mechanisms. Control involves mechanisms that make or are responsive to measurements of conditions within or in the environment of the organism and that operate on flexible constraints in other mechanisms to adjust their operation. A frequent assumption of humans is that control mechanisms are organized in a hierarchical pyramid. However, control in biological organisms commonly deviates from several principles of hierarchical organization and is better characterized as organized heterarchically. To provide a positive understanding of autonomy, this paper advances several features of its heterarchical organization and illustrates them using control of glucose regulation in mammals as an exemplar.

Keywords Autonomy · Control · Organization · Hierarchy · Heterarchy

3.1 Introduction

Organisms consist of components that tend to degrade, yet they maintain themselves far from equilibrium with their environment through a host of mutually dependent activities. These activities 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 behaviors that allow them to move in and interact with their environment. They do not operate under a fixed set of conditions but exhibit diverse activities so as to cope with continuously changing conditions not only in their environment but also within themselves.

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X. E. Barandiaran and A. Etxeberria (eds.), *Outonomy*,
SpringerBriefs in Philosophy, https://doi.org/10.1007/978-3-032-05501-9_3

Since organisms do these things for themselves, they are properly characterized as autonomous (Moreno and Mossio 2015). As we develop in the next section, biological autonomy involves not just organisms producing themselves but controlling themselves: they must determine when and how to carry out the various activities that enable them to maintain themselves. Our concern, to which we turn in sect. 3, is how control processes are organized. Although humans have tended to think in terms of hierarchical pyramids or centralized systems, we argue that biological organisms violate several of the characteristic features of such pyramids and instead are organized heterarchically. *Heterarchy* is often characterized as involving deviation from hierarchy, but in sect. 4 we offer some positive characteristics of heterarchy and discuss how biological organisms have come to be organized in heterarchical ways that are adequate to maintaining themselves.

3.2 Biological Autonomy: Self-Production and Self-Control

In their pioneering contributions to understanding biological organisms as autonomous, Varela et al. (1974) emphasized that organisms are autopoietic—they make all of their own components. To do this, they deploy a host of production mechanisms that enable them to transform materials that they take into themselves and to act in the environment around them, both moving themselves and moving (or otherwise changing) other entities in their environment (see also Ruiz-Mirazo et al. and Virenque, this volume). These are crucial to the ability of organisms to maintain themselves. But these mechanisms also need to be controlled if they are to operate when and in the manner needed to maintain the organism (Bich et al. 2016). Production mechanisms do not operate whenever their substrates and energy are available. Organisms *control* (activate, inhibit, modulate) their production mechanisms and more generally modify themselves and what they (and their parts) do based on their internal physiological state and environmental conditions. For example, consider the activity of metabolizing glucose to pyruvic acid (or alcohol), a process known as glycolysis. It generates ATP, which provides energy for most biological activities. If glycolysis occurred whenever glucose was available and continued until all glucose was consumed, it would waste free energy when it is not needed and deprive the organism of it when it is needed. Accordingly, glycolysis is controlled so as to occur when it is needed.

As we understand control, it involves control mechanisms operating on production mechanisms (or other control mechanisms), changing how they operate. Both production and control mechanisms produce activities by constraining flows of free energy (Winning and Bechtel 2018). Some of the constraints that enable them to perform their activities are (relatively) fixed during the operation of the mechanism, but others are flexible. It is by acting on flexible constraints that control mechanisms can change how other mechanisms operate. In the case of glycolysis, the conformation of enzymes is subject to modification so as either to allow glycolysis to proceed or to divert glucose to another reaction that transforms it into a storage molecule, glycogen, from which it can again be generated when it is needed.

Control involves not just acting on another mechanism, but doing so in response to information about circumstances relevant to whether the activity of the mechanism is required. As discussed by Pattee (1971), such information is acquired by making measurements. This results in changing constraints within the control mechanism, as illustrated by a mechanical thermostat—when ambient temperature changes, constraints are changed (e.g., bimetallic strips straighten or bend) so as to complete (or break) an electric circuit, turning a furnace on (or off). Measurement processes can often be complex and carried out at a distance from the controlled mechanism. When the site of measurement is distant from the mechanism being controlled, a signal must be transmitted between them. Biology is replete with measurement and signalling devices. In the case of glycolysis, the enzyme that initiates the catabolism of glucose can also bind the energy transfer molecule, ATP, when it is plentiful, changing its conformation so that it no longer catabolizes glucose.

Both production and control mechanisms typically contain multiple constraints that together determine their activities. Accordingly, they can be acted on by multiple other control mechanisms or make multiple measurements. As a result, they can procure information about different conditions internal to the organism or in the world external to it, which they then integrate in producing their activity. How they integrate information and what action they perform is determined by how the mechanism itself is organized and how it interacts with other mechanisms in the organism (see Monterde, this volume, for an example). These are not mysterious processes. They are processes performed by a mechanism produced by the organism in the same way it produces other mechanisms—by taking materials, transforming them, and organizing the products in a particular way so that energy is directed through them. Control mechanisms just operate differently by modifying constraints in other mechanisms rather than making products or generating movement.

Control is performed by mechanisms that, together with production mechanisms, constitute the organism. Thus, when control is exercised, it is being exercised by and for the organism. Autonomous organisms (and any other autonomous systems) not only build themselves but control their own operation.

3.3 Organizing Control in Biological Organisms: Heterarchy Vs. Hierarchy

As we just noted, an organism consists of multiple production and control mechanisms. However, it is not just a collection of them, but an organized system. How the component mechanisms are organized is critical —the same components differently organized can generate different behaviors. Since we also noted that control mechanisms can operate on other control mechanisms, a critical challenge in understanding autonomous systems is to understand how control mechanisms are themselves organized (Bich and Bechtel 2022b).

When humans establish social systems—companies, universities, militaries, etc.—they tend to initially organize them hierarchically, generating a pyramid in which groups of workers at the bottom report to one supervisor, several supervisors report to a common higher-level supervisor, and ultimately everyone reports to one chief executive. The assumption is that such a hierarchy is most likely to ensure that all those in the organization are working to promote the whole institution. Central to such organization is a clear ordering of levels from bottom to top. In a variety of contexts such structuring of levels is violated. One such context is with nontransitive preferences in which A is preferred to B, B to C, but C to A. Such preferences clearly violate the hierarchy of levels. McCulloch (1945) introduced the term *heterarchy* for such nontransitive preferences. Heterarchy can be extended to modes of organization that deviate from different features of the pyramid organization. One individual may be subordinate to multiple supervisors. There may be no one agent in charge. There could even be more supervisors than individuals supervised. Crumley (2015) characterizes heterarchies as tangled networks in which elements potentially can be ranked in a number of different ways (see also Pattee 1991). On this view, supervisors and supervised individuals are not defined univocally as belonging to well-delineated levels, but only in regard to a specific activity or relationship. Any supervisor can be in turn supervised by one or more of the individuals she supervises, even skipping intermediate levels. The idea of heterarchy stresses the importance of considering not just top-down but also bottom-up and lateral processes. It identifies a mixed type of organization of control that employs and combines features of both hierarchies (vertical relationship) and networks (horizontal relationship) (Cumming 2016).

3.4 Some Principles of Heterarchy

Heterarchy is usually defined negatively as non-hierarchical. That is both extremely expansive, as it includes every form of organization that is not hierarchical, and non-informative. The challenge is to provide a more positive characterization of the features to be associated with heterarchy so as to be in a position to understand the implications of such features in enabling autonomy.

Considering the space of possible modes of organization, at the opposite extreme from hierarchy are flat networks as studied in graph theory. A graph consists of nodes and edges connecting the nodes. Graph theorists can explain some behavior of systems corresponding to a particular graph in terms of basic metrics such as the mean shortest path between nodes and the average number of connections a node has to its neighbors. Watts and Strogratz (1998) showed that many real-world networks exhibit relatively short mean shortest pathlength and high clustering. Such *small world* networks enable rapid communication across the whole network. Barabási and Albert (1999) explored another metric of network design—the number of other nodes to which a node is connected. In many real-world networks, that is distributed according to a power-law so that many nodes have very few connections, but a few (referred to as *hubs*) have a great many. Such *scale-free* networks are robust against perturbations to nodes or edges.

As useful as such graph-theoretic analyses are in explaining features of real-world systems, they do not distinguish control relations from other interactions between entities. We will develop an account of several features of heterarchical organization according to which it occupies the space between hierarchical pyramids and flat networks and is equipped to explain how control in autonomous systems enables them to sustain themselves.

A first feature of heterarchy that clearly positions it between hierarchy and flat networks is that it maintains a notion of levels, but only defined locally. As we characterized them, control mechanisms operate on the flexible constraints in controlled mechanisms. This allows us to say that a control mechanism is at a higher-level than that which it controls. Sometimes this can be extended to multiple levels—the control mechanism operating on a control mechanism is at a still higher level. In the case of glucose regulation in mammals: glucagon and insulin, released by α- and β-pancreatic cells respectively, control production mechanisms in the liver (also in muscle and adipose tissue) that transform glucose into glycogen for storage. The secretive activities of pancreatic cells are controlled in turn by further higher-order control constraints in the system. These include neurons in the brainstem that stimulate the release of insulin when they receive signals from the gut that food has entered the digestive system or from the eyes when food is visible. On this scheme, the brainstem neurons are at a higher level than β-pancreatic cells which are, in turn, at a higher level than liver cells. But this hierarchical relationship can break down at any point, as with McCulloch's example of non-transitive preferences. For example, it breaks when insulin from β-pancreatic cells modulates the release of neuropeptides. A negative feedback system illustrates this—constraints in the control mechanism operating on a production mechanism are themselves acted on by the product of the production mechanism. Or when two entities both control a production mechanism, one of them may also act on soft constraints in the other, controlling it. The two controllers may be at the same level with respect to the production mechanism that is controlled, but at different levels vis a vis each other. Globally, levels are not well defined in heterarchical systems.

A second feature of heterarchy is that multiple controllers can act independently on one lower-level production mechanism or controller. They may act either on the same constraint in the controlled mechanism, or on different constraints. In either case, conflict can result, with two controllers acting in opposing ways on the same production mechanism. This is comparable to an employee having multiple independent bosses who demand that a given action be performed differently or that each demands an action that is incompatible with performing what the other demands. Sometimes the conflict can be resolved by another locally higher-level controller regulating the controllers making conflicting demands. But often, in both business and biology, that is not the case. The resolution typically rests with the controlled employee or mechanism determining which, if either, of the directives to follow. To continue the above example, circadian regulation and brainstem regulation of the liver can conflict, as when eating occurs at an unexpected time; in such circumstances it is the liver that determines how glucose will be processed.

From the hierarchical perspective, the higher-level controller is in charge—it makes the decision about what those beneath it ought to do. To do so, it brings together information from a variety of sources, often including the entities it regulates, evaluates them according to its own principles (realized as constraints operating within it), and delivers commands. The case of conflicting controllers reveals that in fact the final decision rests with the lower-level controller, or even the production mechanism, the liver in our example. In many cases, a control mechanism integrates inputs both from below and from above in deciding what to do. For example, the brainstem neurons that act on the liver receive inputs not only from the digestive tract but from nuclei in the hypothalamus (to which they also supply information). When multiple lower-level entities provide input to one higher-level entity, and one lower-level entity receives input from several higher-level entities, all act to integrate information and respond to it.

A third feature of heterarchies is that local control hierarchies can be reversed, with mechanisms that are controlled with respect to a given source of information in turn controlling their control mechanisms with respect to another source. Within the local control-hierarchy perspective, lower-level entities act on higher-level controllers by providing information—the measurements they make are communicated by signals that end up altering the constraints in the controller. But they can also act on the controller (or even on a controller acting on the controller)—that is, their output, determined by constraints within them, operates to change constraints in the controller (or, again, in a controller operating on it). In this respect, it is at a higher level than the controller that operates on it. This undermines the prospect of identifying levels globally. For example, insulin released in response to a meal stimulates, among others, pro-opiomelanocortin neurons in the hypothalamus, thus triggering signaling pathways that decrease food intake (Röder, et al. 2016).

A fourth feature of heterarchies is crosstalk. A feature of hierarchical control schemes that we haven't addressed so far is that control at lower levels is segregated—different control streams are independent of each other until they are integrated at a higher level, with some streams only being integrated at the very highest level. This feature is violated if there is crosstalk between the streams. Crosstalk often results when the same components are involved in different control mechanisms, enabling the information procured in regulating one production mechanism to also contribute to the regulation of other production mechanisms. That often happens in regulatory signalling pathways (Bich and Bechtel 2022a). One advantage of crosstalk is that it enhances the likelihood that the activity of one controller will be consistent with that of others, leading to coherent actions. But failure of segregation of different lines of control may also lead to lack of specificity, with controllers failing to respond to local information to which they would otherwise respond. It also makes it much harder to identify the control elements that are responsible for failures so as to address them. The nuclei of the hypothalamus illustrate crosstalk. For many nuclei it is possible to assign one or more physiological or behavioral activity they regulate—the arcuate nucleus regulates eating, the lateral hypothalamus regulates wakefulness, the posterior hypothalamus regulates body temperature, and the suprachiastmatic nucleus maintains circadian time. But the various nuclei project to each other so that, as each regulates one activity, it is modulated by other nuclei regulating other activities.

3.5 Conclusions

We have identified some of the features of heterarchical organizations, features that may provide useful resources to organisms as they organize and integrate their activities. We focused on physiological examples, but these heterarchical control relations can be also instantiated when control relationships are extended in the environment involving two or more autonomous systems, such as in biofilms, multicellular organisms, and symbiotic associations.

A major challenge remains—explaining how a heterarchically organized system can act in ways that enable it to maintain itself as an autonomous system. Those designing machinery to operate in a given environment typically impose a hierarchical design. In such a design, they can anticipate how the system will respond to each perturbation, processing information and generating responses. One problem with this type of organization is that controllers higher in the hierarchy need to be increasingly complex and able to manage more and more information. Another problem is that a failure in one control mechanism high in the hierarchy can have cascading effects on the operation of all the lower-level mechanisms whose behavior depends on it. Heterarchical organizations instead are much more flexible. Distribution of control and the fact that final decisions often rest with the lower-level mechanisms does not require centralization of information processing and so makes systems less subject to cascading failures. Heterarchical systems, however, are much more difficult to understand as information flows in diverse ways through the system, and individual control components often alter the operation of multiple production mechanisms. This presents challenges to someone trying to modify or repair such a system—a given change in the system can have multiple effects beyond those anticipated. It also presents challenges to understanding how a heterarchical organization could enable organisms to maintain themselves as autonomous systems. A randomly assembled system would be unlikely to maintain itself. Among the possible ways of organizing the same components, probably very few would actually suffice to keep the organism going.

If a system is being designed by rational agents, it may indeed be difficult for them to arrive at a successful heterarchical design. But biological systems are not designed. They have evolved over an extremely long period of time in which variations are successively introduced and those variants that succeed in maintaining organisms sufficiently long to leave offspring are maintained. Although approaching the organization of organisms as an engineering problem is problematic, some insight can be acquired by considering a scenario in which you are charged with improving the performance of a system (e.g., a computer program or a company) that is operating moderately well. Unlike biological systems, let's further assume that the system assigned to you was initially organized in a hierarchical pyramid. You identify a particular context in which performance might be improved and hypothesize that it would be improved if a new control relation was added that violated the pyramidal organization—e.g., you allowed a second controller to act on the same controlled component. You make many additional changes in the same way: if, in the context in which the system is supposed to operate, overall performance improves, or at least doesn't deteriorate too much, the modifications will be incorporated into the system. When your successor takes over, she proceeds in the same way. Along the way the control exercised by the top-level controller is diminished as you add additional lower-level controllers, or connections between them, that improve performance. Before long, any semblance of the hierarchical pyramid will be lost. The explanation for how such a heterarchical organization could become instantiated is that it developed over time, with each addition being added when it maintained or improved performance.

This thought experiment offers a small example of the processes by which organisms acquire organization through evolution (except that they almost certainly did not start out with a hierarchical pyramid). As Partridge (1982) argues, evolution is not engineering, and the organization that results may not be one that is readily understood by us. The relevant consideration is whether it enables the organism to maintain itself as an autonomous system. To better approximate biological evolution, we need to take into account the fact that the environment in which organization is evaluated does not stay fixed but is constantly modified, both as the physical environment changes and as other organisms change. In the changed environment, what matters is that the modification enabled the organism to continue to maintain itself and reproduce (see also Menatti, this volume). But when we consider changing environments, we can identify a further virtue of the heterarchical organization. In a strict hierarchy, the loss of a component is likely to have a distinct effect (typically negative) on performance. But as a component is subject to multiple controllers, and these control relations become more entangled, there are more pathways by which it may get the information needed to perform. It is not dependent on a single supervisor doing its job (or doing it well). As a result, heterarchical control schemes that have developed through iterated modifications as in evolution are likely to be more robust. Accordingly, they advance autonomy.

3.6 Funding

LB acknowledges funding from IAS-Research group funding IT1668–22 (Basque Government); grants PID2019-104576GB-I00 "Outonomy" and PID2023-147251NB-I00 "Outagencies", funded by MCIU/AEI/10.13039/501100011033 and FEDER/UE.

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Part II
The Fabric of Life

Chapter 4
Environment(s), Autonomy and (A)Symmetries

Arantza Etxeberria

Abstract This chapter examines conceptualizations of the environment in biology and addresses the different organism/environment asymmetries appearing in autonomy views and evolutionary theories. It argues for recognizing the environment not merely as an external background, but also as co-constitutive and relational, insofar as life is shaped by epigenetic, exposomic, and interorganismal dynamics. Two perspectives emerge, environments as surroundings and as entanglements, both required for developing an "outonomy" framework that expands biological autonomy theory to include environmental agency and interdependence.

Keywords Epigenetics · Exposome · Milieu · Plasticity · Relationality · Holobiosis

> *"The notion of milieu is becoming a universal and obligatory mode of apprehending the experience and existence of living beings; [...]it is now being constituted as a category of contemporary thought [...] philosophy must take the initiative in synoptically investigating the meaning and value of this concept."* (Canguilhem 2008, 98)

4.1 Introduction

The environment is an elusive concept, highly polysemous, deeply entangled with history, and difficult to define precisely in science and medicine. Yet, in recent years, it has emerged as a philosophical subject in its own right, demanding attention beyond its conventional role of being merely the background to living beings. This shift signals a growing recognition of the environment's complex multifaceted philosophical significance across disciplines, particularly in biology, medicine, and environmental philosophy. Conceptually, it is riddled with tensions: whether the environment

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X. E. Barandiaran and A. Etxeberria (eds.), *Outonomy*,
SpringerBriefs in Philosophy, https://doi.org/10.1007/978-3-032-05501-9_4

is a passive stage or an active force, an external domain or an internal one, and whether it is defined by intrinsic properties or by relations. These questions could reshape our understanding of the environment and prompt a reconsideration of its role in shaping life itself.

This chapter outlines the role of the environment in biological thought, contrasting its significance in organizational and evolutionary theories within biology. It provides an overview of key narratives about the concept of the environment in science and philosophy, explores organism-environment systems, and the symmetries and asymmetries shaping their mutual influences. The analysis suggests that accounts of autonomous systems require expanding to embrace relational dimensions, with the recognition of the environment as an active participant being central to conceiving autonomy as *outonomy*.

4.2 What Is/Are (the) Environment(s)?

Several distinct narratives of the environment can be identified in current science and philosophy, each serving a different purpose. One of them, articulated by Georges Canguilhem in *The Living and its Milieu* (Canguilhem 2008), examines the environment as a counterpart to the organism. Canguilhem traces the history of the milieu within the organism-environment pair, arguing that organisms are internally regulated systems that, as wholes, maintain relations with their milieu similar to the interactions among the parts that constitute the system itself, engaging in mutual influence rather than a simple cause-and-effect (Etxeberria 2020). The concept of milieu, originating in Newtonian mechanics as a fluid medium (ether) that mediated between bodies and transmitted causal action, later appeared in biology with Lamarck's "milieux" and Darwin's "conditions of existence." Although Darwin didn't use "environment" in *On the Origin of Species*, Herbert Spencer popularized the term in the late nineteenth century (Pearce 2010). At this point, "environment" emerged as a singular, abstract concept, meaning the external correlate of the organism, itself an abstract concept. The concept evolved further, with Bernard introducing the "internal milieu" for physiological regulation, Comte unifying physical surroundings and influential circumstances, von Humboldt conceptualizing a global environment, and von Uexküll defining "Umwelt" as each species' enacted sphere of significance. For further elaborations, see Pearce (2010), Casetta (2025), and Fábregas-Tejeda (2025).

A second line of thought addresses our understanding of environmental phenomena in relation to planetary life in fields like *Earth Systems Science* (Warde et al. 2018). This perspective presents *the environment* as a singular, global concept emerging post-World War II, highlighting its status as both a scientific and social construct, particularly in its modern, global dimension. Unlike "nature", which is often associated with intrinsic properties, "environment" is frequently understood as relational, constituted by interdependencies among systems.

A third perspective regards environments as inherently plural, reflecting diverse cultural understandings, roles (such as resource, habitat, threat, or partner), and approaches ranging from indigenous knowledge to modern science. This plurality suggests that environmental thinking resists reduction to a single framework, instead drawing its richness from multiple interpretations: as physical space, relational network, cultural construct, and field of action (Benson 2020).

The essay will primarily focus on how the environment is conceptualized in relation to organisms in biology and medicine, while also returning at the end to how expansions of biological views influence the other two main understandings of the concept.

4.3 Organism/Environment Asymmetries

The organism/environment system was conceptualized through opposed asymmetries in autonomous systems accounts and evolutionary theories.

4.3.1 The Internalist Asymmetry of the Autonomy Perspective

The autonomy theory of the organism can be traced across a historical critique of various deterministic accounts of life and living systems, ranging from mechanistic conceptions of organisms as machines, to notions of the *milieu* as a deterministic force, to evolutionary externalist accounts emphasizing the role of selection as a form of design.

The development of biological autonomy theory traces a rich intellectual lineage, starting from Kant's idea of self-organized beings. Key further contributors include Claude Bernard's work on internal stability and Walter Cannon's concept of homeostasis (Bernard 1974; Cannon 1929). These notions laid the groundwork for understanding biological self-regulation, which proved highly influential for cybernetics. This framework was further developed by second-order cybernetics theorists, particularly Maturana and Varela's theory of autopoiesis, while Stuart Kauffman contributed about how internal constraints generate biological autonomy against entropic tendencies. This theoretical progression led to the organizational approach, including the one developed by the San Sebastian group, which emphasizes how living systems maintain themselves through complex self-regulatory processes that generate their own constraints and enable their continued existence (Moreno et al. 2008; Moreno and Mossio 2015).

This tradition of biological autonomy has frequently relegated the environment to a secondary role, either as a mere facilitator of autonomous processes or as a source of disturbances to be resisted. Various philosophical perspectives, such as Spinoza's idea that passive affections are harmful, have contributed to this negative view of environmental influences, and Bernard's notion of the constancy of the *milieu intérieur* as a condition for a free and independent life was especially influential (Bernard 1974). More recently, this view states that a "broad agential autonomy implies that the organization of the system causes the processes exerted on the environment, whereas those of the environment towards the system are monitored according to internally defined needs" (Moreno et al. 2008, 312).

All this reveals an asymmetry in how organisms and environments are understood: organisms are seen as active agents, whereas the environment is reduced to a passive enabling background. This bias may stem from individualistic ideals, but the idea of autonomy as freedom from the environment requires reevaluation. As relational phenomena organisms are not fully independent, they are inherently open to environmental influences, constantly sensing and responding to change. This dimension is required for their goal-directed and purposeful existence.

4.3.2 The Externalist Asymmetry of Evolutionary Theory

In evolutionary thinking, the organism-environment relationship was framed through adaptation to selective pressures, favoring a functionalist view of organisms. While the earlier Kantian Cuvier saw functions as internally articulated, Darwin viewed traits as evolutionary solutions to environmental demands. With the "hardening" of the Modern Synthesis (Gould 1983), genes became the primary units of adaptation, reinforcing an externalist *asymmetry* where environmental pressures shape genes, but organisms do not act on the environment (Cortés-García and Etxeberria Agiriano 2023).

Philosophers of evolutionary biology have examined the role of the environment. Robert Brandon (1990) identifies three types: the external environment (all factors outside the organism), the ecological environment (those within a specific area), and the selective environment (factors affecting reproductive success). However, this framework focuses on shared environments influencing populations, not the dynamic, reciprocal relationships between organisms and environments. As Walsh (2022) notes, the shared environment is a theoretical abstraction that overlooks the occurring complex, multifaceted interactions organisms actually engage in (see also Fábregas-Tejeda 2025). Organisms actively shape their environments and developmental trajectories, as critics of adaptationism contend. Thus, organism-centered approaches to evolution challenge classical externalism recognizing that organisms actively influence, rather than passively adapt to fixed conditions (Levins and Lewontin 1985; Baedke et al. 2021). They emphasize the constructive capacities and internal organization of organisms (Walsh 2015; Alberch 1989; Etxeberria and Nuño de la Rosa 2021), while recognizing the active causal role of environmental factors. Some views of niche construction admit that the environmental influences can be either to change the environment or to change the organisms themnselves. Some perspectives within Niche Construction Theory hold that constructing a niche may entail both environmental changes and organismal modifications that reshape how they experience it (Chiu 2019). These perspectives soften the Modern Synthesis's externalist asymmetry and align closely with autonomy theory and enactivism.

4.4 Towards Organism/Environment Symmetries

The preceding discussion outlined how both autonomy theory and evolutionary biology often uphold asymmetries: the former minimizes the environment's role, while the latter treats organisms as passive responders. These views are increasingly contested by approaches that emphasize dynamic, reciprocal organism-environment relations. This section examines how epigenetics and exposomics reconceive the environment as an active, co-constitutive element in biological individuation.

4.4.1 Epigenetics

Epigenetics offers a key framework for understanding how the environment co-constitutes living systems, showing how social interactions and contingent relationships can influence gene expression without altering DNA. Neural epigenetics, for instance, links social experiences to molecular changes like DNA methylation, integrating environmental inputs into an organism's biological constitution (Nicoglou and Merlin 2017).

Conrad H. Waddington's early work conceived epigenetics broadly, taking into account the entire developmental process and its underlying causal basis. In contrast, contemporary molecular epigenetics focuses on specific pathways, such as chromatin modifications, maternal imprinting, and small RNAs, through which environmental factors affect gene regulation without altering the DNA sequence. Thus the environment's active role in gene regulation and biological development is highlighted, moving beyond the notion of a passive background for genetic programs (though see Loison 2022 for distinctions between them).

Epigenetics thus shifts our understanding of biological complexity from hierarchical control to interdependent organizations of connected elements, emphasizing notions of *connectivity*, *crosstalk*, and *exchange* among elements (Buklijas 2018), and calling for an analysis of heterarchies (Bich and Bechtel 2025, this volume). These insights suggest the need to revise autonomy theories to emphasize relational co-constitution. One way forward is to reconsider the distinction between constitutive and interactive autonomy proposed in the organizational framework (originally outlined in Moreno et al. 2008), particularly the assumption that organisms are constituted prior to their interactions. Barad's agential realism offers an alternative framework for this relational constitution (Barad 2007). In this light, processes such as learning, metabolic plasticity, and other adaptive changes can be seen as co-constitutive.

4.4.2 Exposures to Environmental Influences

The study of environmental exposures reveals the permeable nature of living bodies, constantly influenced and traversed by their environments, entangled with them rather than merely surrounded by external conditions. This challenges the conventional view of autonomy as self-production. Hannah Landecker (2017) critiques the metabolic conception of autonomy rooted in Claude Bernard's idea of digestion, where consumed material becomes "inert raw material" and fully assimilated into the eater. She argues instead that ingested genetic material can persist and function in the host, forming symbiotic or commensal relationships rather than being entirely broken down.

This biological porosity, documented in epidemiology and the emerging field of *exposomics*, contests the idea of strict boundaries between organisms and environments. Exposomics, developed in the post-genomic era, examines the full range of environmental exposures (i.e., the *exposome*) and their health effects by analyzing thousands of factors at once (Wild 2012). It redefines the concept of environment to include both external factors and the body's internal chemical landscape, encompassing both exogenous compounds and endogenous molecules alike (Rappaport and Smith 2010). Exposures thus refer not only to substances entering the body but also those produced within it, offering a notion of the exposome as everything in the body that is not genetic (Wild 2012; Canali and Leonelli 2022; Pontarotti and Merlin 2023).

Epidemiology offers two main perspectives on the environment (Shostak 2013) with a molecular approach, exemplified by exposomics and social epidemiology, which focuses on social variables such as "neighborhood effects", suggesting that where one lives (postal code) may be as biologically significant as one's genetic code. Nancy Krieger argues that it is bodies, not genes, that narrate stories of existence through exposure, susceptibility, and resistance, showing how social inequalities become biologically embodied, for example in the form disease (Krieger 2005).

The concepts of *exposed science* (Shostak 2013) and *permeable corporeality* (Begueria and Zafra 2019) stress that bodies are relational and dynamic, actively engaging with their surroundings. This permeability reflects a balance between receptivity and agency, where bodies both shape and are shaped by their environments (Menatti 2025, this volume). The notion of exposure shows how environments permeate organisms, and this reinforces a view of autonomy grounded not in isolation, but in ongoing relations.

4.5 Interorganismal Interdependences and Holobiosis

Previous sections examine how the environment is viewed as having a direct causal impact on organisms, rather than being a passive backdrop. However, this causal influence is typically understood in physical or chemical terms, such as temperature, light, or nutrient availability, rather than an influence exerted by other organisms. However, as Canguilhem observed, Darwin's approach differs in that it prioritizes inter-organismal relationships over the consideration of the milieu as merely physical surroundings (Etxeberria 2020, 2023): *"The fundamental biological relation, in Darwin's eyes, is the relation of one living being to others; it prevails over the relation between the living and the milieu conceived as an ensemble of physical forces. The first milieu an organism lives in is an entourage of living beings, which are for it enemies or allies, prey or predators"* (Canguilhem 2008, 105). Canguilhem rightly notes that Darwinian biology emphasizes inter-organismal relations, but these are largely framed as competitive interactions that impact individual fitness. This perspective is now changing as emerging views frame evolution as involving genuine organismal entanglements, challenging individualist paradigms. By treating organisms and their environments, including other organisms, as mutually constitutive, this shift redirects focus from discrete entities to processes of exchange and connectivity, demanding new ontological frameworks.

In this sense, Lynn Margulis's concept of the holobiont redefines our understanding of organisms, viewing them as assemblages or consortia of entities in symbiotic relationships (Margulis 1991; Baedke et al. 2021). Rooted in her theory of symbiogenesis, this framework explains how new kinds of living entities emerge through long-term collaborations, where relations become so integrated within new unified systems.

Such interconnectedness is further exemplified through biological and social relationships. Eutherian pregnancy, for instance, involves physiological and immunological interplay between gestator and embryo (Etxeberria and Nuño de la Rosa 2021, Etxeberria and Cortés-García 2024).

Early caregiving similarly influences development, through behavioral bonds which are the basis for "social markers", or measurable indicators of relationships that affect biological processes. These cases challenge the notion of organismal independence, showing that identity is co-constituted through lasting relationships with others. The perspective of holobiosis captures aspects of a broader shift in biology, according to which organisms are now increasingly understood as part of dense webs of interdependencies. The environment is now an active, dynamic network of relations that shape and are shaped by living systems (Barker et al. 2014).

This view becomes especially urgent in light of the growing interplay between natural and artificial environments—highlighted by the fact that anthropogenic mass now exceeds Earth's biomass (Elhacham et al. 2020). Within this context, decomposition is as fundamental to life as composition itself; the breaking down of materials is equally important as their assembly. Decomposition, decay, and death are not opposite to life, but essential processes that sustain its cycles and balance. From this entangled perspective, the environment is neither wholly external nor internal to organisms, who maintain identities linked to their environments, actively engaging in mutual influence.

4.6 Two Environments: Surroundings and Entanglements

This essay has examined two expanded concepts of the environment. The first understands environments as external surroundings, considering their influence on life and health. As *surroundings*, environments are the physical, chemical, and biological contexts that influence individuals and sustain communities, then including shared environments (Fábregas-Tejeda 2025). Thus although “the environment” appears as a global entity, environments as surroundings can also be multiple, partial, and specific to particular locations. In biology, it aligns with views of organisms as plastic and ecologically embedded, such as the holobiont concept. In medicine, it relates to research on exposures, microbial communities, and cultural practices.

As *entanglements*, the second perspective favors understanding environments as networks of entangled relations, thus primarily constituted by other organisms. Here, the environment is not an external force but a co-constitutive agent, changing how we understand ecological and relational networks. Biology increasingly adopts this view, seeing environments as dynamic systems of interdependence, beyond mere surroundings.

The two concepts of environment have different implications for how we understand life and ecological relationships science, philosophy, and environmental thought. The view of a global understanding of the environment as a matter of ethical and political concerns remains linked to a view of environment as surroundings which remains largely asymmetrical and is pictured as an independent entity which needs to be cared after. In contrast, the entanglement model aligns with biodiversity concerns and feminist and relational ontologies, which emphasize fluid boundaries and mutual constitution (Haraway 2016; Barad 2007; Cabello et al. 2025, this volume).

The symmetry perspective sees environments as agential, living or produced by living beings. Though unconventional, it reflects the reality that most environments are composed or constructed by other living forms. The internalist asymmetry is required to better examine the organization of living systems, which may include the generation of system boundaries, while the notion of ‘outonomy’ signals a shift toward recognizing their porous nature as co-produced, interconnected systems. Hence, both conceptions of the environment remain essential to contemporary scientific inquiry.

4.7 Acknowledgements

I thank the reviewers for their valuable comments. This research was supported by the Basque Government [IT1668–22], grants PID2019-104576GB-I00 for project Outonomy and PID2023-147251NB-I00 for Outagencies funded by MCIU/AEI/ 10.13039/501100011033 and FEDER/UE, and the ‘Metaphysics of Biology’ project [PID2021-127184NB-I00].

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Chapter 5
Outonomy at the Origins of Life

Kepa Ruiz-Mirazo, Alvaro Moreno, and Ben Shirt-Ediss

Abstract The first living beings, prokaryotes, were endowed with an extremely complex and dynamic individual organization: a compartmentalized metabolism in which diverse molecular components and transformation processes got functionally coupled, including a selectively permeable membrane, a set of energy currencies and a translation apparatus built upon a common genetic code. Each microorganism neatly distinguishes itself from the surrounding medium and is capable of generating and modulating its own rules of behaviour (i.e., it acts on its own behalf) so it can be interpreted as *autonomous* in a fundamental biological sense. However, the autonomy theoretical framework only covers part of the explanation for the striking complexity observed in minimal lifeforms. In fact, all known living cells depend on other cells for their sustenance, so they engage in diverse ecological relationships without which their survival would not be feasible. Furthermore, all living cells have arisen from pre-existing cells, through reproduction, within a long-term, open-ended evolutionary process. As we will argue below, the constitution of any biological domain requires a strong –though deeply asymmetric– causal interweaving between individual (*metabolic-physiological*) and collective (*ecological* and *evolutionary*) dynamics, covering different spatial and temporal scales that unfold in the course of abiogenesis.

Keywords Origins of life · Prebiotic *systems* evolution · Ecopoiesis · Biological autonomy · Agency · Dynamic decoupling

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X. E. Barandiaran and A. Etxeberria (eds.), *Outonomy*,
SpringerBriefs in Philosophy, https://doi.org/10.1007/978-3-032-05501-9_5

5.1 Introduction: The 'Protocell Scenario' and a Few Preliminary Implications

The last universal common ancestor of all life on Earth (LUCA) was a population of prokaryotes. Although the specific properties, diet, local habitat or degree of phenotypic heterogeneity of those systems may still be controversial, few scientists doubt that they constituted a large group of unicellular organisms performing 'genetically-instructed' (i.e., ribosome-/code-mediated) metabolism (Moody et al. 2024). Before the appearance of that fundamental microbial threshold, we don't really know what happened. The absence of natural, physical–chemical systems of intermediate complexity could be due to life's voracity or to the fact that terrestrial conditions have changed so dramatically over the years that they no longer allow for the emergence of alternative lifeforms. However, this state of affairs is truly intriguing, because the compositional, organizational and behavioural complexity of individual microorganisms is many orders of magnitude higher than any other non-biological system we find in nature.

The huge 'complexity gap' between extant living vs. non-living systems[1] holds a profound message for us to unravel, and far-reaching implications that we just barely grasp. One has to do with the source of biological causality, a rather difficult, slippery topic. Current understanding of non-equilibrium physics and chemistry has moved beyond the classical Newtonian view of matter as passive and inert: we now consider that self-organizing forces/principles play fundamental roles in nature (Nicolis and Prigogine 1977), including biological phenomena at different levels (Saha and Galic 2018). Hence the trend to incorporate such intrinsic dynamics in our explanations about primordial biogenesis, as well (Nogal et al. 2023).

Yet, in addition to self-organization and self-assembly processes, probably combined in non-trivial ways (Showalter and Epstein 2015; Chen et al. 2022), a material system with biological potential entails the interplay of several, self-induced, control mechanisms at once. On these lines, we have claimed over the years (Ruiz-Mirazo and Moreno 2004; Lauber et al. 2021) that proto-biological organization requires the production and functional integration of molecular constraints of various kinds (i.e., *kinetic*, *spatial* and *energetic* controls) to actively maintain itself in non-equilibrium conditions and achieve what we coined 'basic autonomy', in an attempt to complement other, more abstract, classical proposals (Varela 1979; Ganti 1987; Rosen 1991; Kauffman 2000).

Incipient physical–chemical self-constraining/self-maintaining systems would thus develop into minimal metabolisms (Lauber et al. 2021) through coupling with organic compartments in aqueous, heterogeneous media. This hypothesis is supported by extensive experimental evidence on the prebiotic plausibility of the

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[1] 'Infra-biological' entities, like viruses or other types of –molecularly very sophisticated– parasitic systems, which function thanks to the metabolic activity and machinery of prokaryotes, do not dwell in that intermediate region between physics/chemistry and biology: they definitely belong to the biological domain and play important roles within it, even if they are not living beings themselves (Moreira and Lopez-García 2009).

molecular building blocks and elementary reaction networks involved (Nogal et al. 2023) and has also been explored and tested through various computational models (Ruiz-Mirazo and Mavelli 2008; Piedrafita et al. 2017). In more general philosophical terms, conceiving protocells as primary autonomous systems has helped to elaborate a non-reductionist *organizational* account of biological functions (Mossio et al. 2009), or even to ground teleological explanations (Mossio and Bich 2017), starting from very early prebiotic stages. The self-determination dynamics of these minimal metabolic systems would inaugurate a novel and recursively cyclic causal regime (Moreno and Mossio 2015) upon which all subsequent living beings would build.

If we accept 'basic autonomy' as a key transition for the onset of life, a first 'internal/external' causal asymmetry slides into our prebiotic explanations, given the increasingly complex and distinct molecular transformations occurring within the compartment, as compared to its surrounding milieu. Furthermore, as non-equilibrium open systems, metabolizing protocells must continuously capture and release matter-energy to implement and maintain their identity, including their physical interface with the external world, which necessarily involves an *active* tuning of their local boundary conditions. In other words, self-constructing protocells cannot help being *agents* from the beginning, even if this should be taken in a minimalist, crudely foundational sense (Barandiaran et al. 2009). Thus, our approach puts a lot of emphasis on the individual system, the protocell, as the main axis of prebiotic activity, reinforcing the 'in–out' asymmetry not only in compositional but also in processual and behavioural terms. Protocells would constitute, in this way, the main loci and channel for biologically relevant processes to come forward, which can be spelled out as endogenous metabolic activity and outward action.

Accordingly, although we will defend that protocellular systems –if they are to turn cellular, fully biological– must establish additional collective and trans-generational causal relationships, it is important to highlight that these larger-scale spatial and temporal interactions *spring from* and *sediment in* their individual organization. In other words, under the theoretical framework we propose for primordial biogenesis, individual protocells remain both the source and sink of all the novel causal powers that unfold during the transition, even if those come thanks to their belonging to a *population* of interacting and reproducing autonomous entities. In such a scene, as described in the next two sections, collective action essentially takes shape in a twofold manner: ecological and evolutionary.

Many issues of interest can be discussed within this rich prebiotic arena (Ruiz-Mirazo et al. 2020), but our focus here will be on how some populations of protocells may come up with molecular mechanisms through which processes that expand beyond the individual sphere somehow feed back into it, making later protocells increasingly complex and adaptive. We shall argue that the appearance of 'hereditary templates' (oligomers whose characteristic linear sequences can be replicated through base-pairing and then transmitted via reproduction), as expected, must play a critical role in this regard, together with 'higher-order controls' (regulatory molecular constraints), because they enable the simultaneous increase of both protocell complexity and robustness, under highly variable environmental conditions. Therefore, by the time the origins-of-life process is completed, those protocells that manage to combine *regulatory* and *hereditary* mechanisms in such a way as to distil the learnings of all that prebiotic collective effort, across a huge number of subsequent generations, will no longer be protocells: they will already constitute living cells in their own right.

5.2 Matter and Energy Cycles Beyond the Individual: Ecological Networks and Collective Action as a Fundamental Requirement for Abiogenesis

Before we address the crucial impact that the development of reliable heredity and regulation had on protocell organization, functional/agent behaviour and proliferation, it is important to highlight that protocellular individuals never stood alone. Even at the first stages of abiogenesis, when protocells formed spontaneously and underwent diverse physical–chemical transformations (mostly due to exogenous forces), they were part of highly heterogeneous populations (similar to vesicle suspensions that one can prepare in vitro). The simpler the protocells, the simpler the features that reflect that heterogeneity: e.g., global size, shape, molecular composition, membrane permeability/fluidity, etc. (Piedrafita et al. 2017). In any case, the current picture of the process of origins consists in a progressive transition from primordial ('messy') instances of chemical/protocell heterogeneity (Szostak 2011) towards more and more sophisticated versions of it, eventually akin to those we observe in extant cell populations.

In this scenario, where molecular diversity is the rule rather than the exception, one can easily imagine different chemistries arising independently, in a variety of compartments, and then combining through protocell fusion events (Carrara et al. 2012), or coupling indirectly by means of a smaller pool of intermediate compounds that are cycled through the local environment (waste products, nutrients, etc.—depending on the type of protocell/proto-metabolism under consideration). As division events become more frequent and reliable, fostered by endogenous chemistries, protocell proliferation rates shall accordingly increase, and the material and/or energy resources required by these non-equilibrium systems will become a strong limiting factor. At that point, competition forces may appear and lead to the "survival of the fittest", inducing more homogeneity in the population (like autocatalysis could also do, at a more basic molecular level). However, nature is intrinsically stochastic, providing many sources for chemical and system variability. In addition, experimental and theoretical models of bacterial ecology have demonstrated that "cross-feeding" or "mutual sustenance" among cell species is not only possible but may well be the norm (Posfai et al. 2017; Pacheco et al. 2019).

In this way the origins of syntrophic relationships and "ecopoiesis" (Guerrero 1998) can be envisioned in a prebiotic scenario, since the first self-(re-)producing protocells would face not only scarcity of some essential nutrients but also the potential contamination of their local environments due to the accumulation of waste/

leakage products. Under such conditions, spontaneous metabolic shifts to adapt to the new circumstances should be naturally expected: namely, protocells benefiting from new feeding opportunities and collectively engaging with others in matter and energy exchanges that expand and, at the same time, interlock the endogenous chemical transformations that take place within each of them.

From this perspective, the development of agent capacities (i.e., diverse protocell-protocell interaction mechanisms) by the members of the population is pivotal: both for each individual to respond to external challenges and endure over time and for their collective maintenance, as a whole—which in turn contributes to more efficient versions of the metabolism performed by single protocells. Therefore, a reciprocal but asymmetric reinforcement occurs between two parallel dimensions of the phenomenon: (i) the metabolic dynamics carried out by protocells, thanks to the cyclic and highly integrated organization of their internal components; and (ii) the ecological relationships that involve global resource allocation/distribution (cross-feeding, etc.). This type of bolstering connection, which will re-materialize later, at different stages of evolution (see, e.g.: [Etxeberria 2025; Cabello et al. 2025, this issue]) is reciprocal because one dimension cannot exist without the other (there is no physiology without ecology, and vice-versa), but asymmetric in the sense that individual protocells remain the principal source of activity, the main "performers" or "transformers" of causal power and action. Thus, we speak about protocell *organization*, whereas (relatively less integrated or looser) ecological interconnections are regarded as *networks*.

5.3 Climbing the Ladder of Complexity Towards Biological Autonomy: 'Dynamic Decoupling' Mechanisms as the Key Towards Open-Ended Evolution

Even if some self-producing protocells could establish proto-ecological networks and become sufficiently robust to sustain themselves and proliferate on the planet, the long-term maintenance of the living phenomenon (across geological time scales) is still quite remarkable. And more so if one realizes that any material system, especially under precarious, non-equilibrium conditions, inherently tends to decay, accumulate defects, etc. How did nature overcome these difficulties, bringing about an incredibly wide range of efficient and adaptive metabolisms, colonizing the whole surface of the Earth and remaining there until the present day?

Answering this question brings us down to the problem of how a complex system may achieve its own *reproduction*. Biological organization is ensured and thrives, in practice, via growth and division of individual living beings, establishing a historical causal entailment through which they perpetuate. One could even say that the hard-core problem of the origins of life is achieving reliable reproduction of complex, self-producing, autonomous systems. But this challenge is huge because efficient and adaptive metabolisms require an increasingly complex organization, which involves very heavy material/energetic demands: in particular, reliable reproduction needs specific molecular recording mechanisms, arranged within a given system architecture, so that the intermediate levels of complexity generated on the way don't get degraded and lost. Almost a century ago, von Neumann had the deep insight that there is a threshold of complexity below which any "universal constructor" would decay and above which it would be able to maintain itself, via self-reproduction, and start a process of open-ended evolution (McMullin 2000; Ruiz-Mirazo et al. 2008). The formidable quest of natural physical systems that may eventually turn biological is, indeed, reaching the von Neumann threshold/architecture without disintegrating on the way.

Protocell reproduction plays a critical role here because it leads to *lineages*, which transform into actual *families* (groups of closely similar individuals, related via common ancestry) within the overall population. This adds a completely new historical dimension to the emerging phenomenon. The more reliably reproduction is accomplished, the deeper the protocell lineage, and the bigger the weight of the corresponding family, in the population, over time. New protocells, in this way, become the result of the self-making of previous protocells, transcending their individual sphere through consecutive growth and reproduction cycles (Ruiz-Mirazo et al. 2020). All of this, of course, has a significant impact on the overall population dynamics, including the potential to extend the influence of a change/innovation far beyond the spatial and temporal coordinates of the individual organization where it first occurs—by virtue of the role it plays in a later coming, similar individual.

Thus, protocell populations evolve across prebiotic times, comprising a high number of trans-generational trajectories that contingently intermingle, combining different factors (physiological, ecological, reproductive…) under global matter/energy limitations, which impose further restrictions and tension on the interactions. Natural selection and other evolutionary forces operating on the population shape the progressive, historical outcome of this multi-scale, collective process. The evolutionary process itself is transformed, thereby, as new individuals, with novel features, take over the population. In brief, prebiotic evolution transforming into proper *biological* evolution. For all of this to happen, the key lies in the development of molecular mechanisms that contribute to solve, at once, two hard –apparently unrelated– problems: (i) improving the robustness and adaptivity of the individual protocells and (ii) registering and transmitting, via efficient reproduction, their level of complexity (including potentially beneficial variations) to their offspring, in a way that allows subsequent protocells in the lineage to retain that complexity and avoid decay.

The solution to this double problem is particularly challenging because those molecular mechanisms must be embedded –and have direct effects– in the recursively cyclic and functionally integrated (metabolic) organization of each protocell, while making lineages more reliable and profound in a linear, historical sense. The first steps towards the end of this tunnel were surely taken when protocells started synthesizing molecular templates (e.g., RNA oligonucleotides) with capacity *both* for replication (sequence conservation) *and* for the specification of new (more elaborate and accurate) constraints on their individual metabolism: in other words, material ‘records’ that could not only be faithfully *transmitted* to other individuals in the population, but also physiologically *interpreted* by each of them (Pattee 1969).

Nevertheless, together with this incipient ‘self-recording/self-interpreting infrastructure’, the production of second-order control mechanisms was also crucial. The reason is that any complex dynamic organization, articulated through the synthesis and functional integration of its component parts (like the metabolizing protocells described above), needs to explore a wide range of states/behaviours, as it faces multiple variations of both internal and external conditions. Being precarious (non-equilibrium) systems, effective navigation of those large phenotypic spaces requires dedicated meta-control mechanisms so individuals can respond quickly and adequately to a given challenge, finding the specific stationary state –or behavioural strategy– that solves the problem, which ultimately requires the modification of primary controls on metabolism. But that’s precisely what biological regulation involves (Bich et al. 2016): endogenously produced material controls operating on other controls in such a way that global system robustness and adaptivity are enhanced.

Although the primordial, natural origin of regulatory mechanisms is still an open question, in our view it is deeply connected to prebiotic evolutionary dynamics and, more precisely, to the capacity that some protocells developed to “learn” from the experience (i.e., from the “trials and errors”) of previous and contemporary individuals in the population—outcompeting members of their own or other families, sharing and collaborating with some others, etc. (Ruiz-Mirazo and Moreno 2024; Shirt-Ediss et al. 2024). Thus, regulation might have appeared, for the first time, when protocells started implementing reversible metabolic shifts to face nutritional challenges (e.g., similar to the ‘Lac-operon mechanism’ in extant bacteria); or in the context of their response to viroid infections, leading to early versions of microbial immunity (e.g., something like the CRISPR-Cas defence system); or directly operating changes in external conditions (e.g., by means of selective secretion, or controlled change of spatial position) which become functional, feeding back into the protocell individual and enhancing its “adaptive agency” (Di Paolo 2005).

What is important to realise is that all these mechanisms serving as ‘material memory’ of the dynamics of a population, across generations –be them hereditary or regulatory– must operate “off-line” with regard to the internal functioning and external behaviour of individual systems: in other words, they are *dynamically decoupled* from the basic metabolic workings of the organism, even if they remain *hierarchically coupled* to them (Pattee 1969; Ruiz-Mirazo and Moreno 2024), contributing to the whole system robustness, plasticity and adaptive capacities. Such is the trick that nature invented to generate, maintain and potentially increase the complexity of the biological world: produce individuals with a highly sophisticated organization of controls, operating at different rates, which represent a much longer, historical and inherently collective process.

5.4 Conclusion

The estimated time window for primordial biogenesis to be completed was of the order of hundreds of million years. This incomprehensible figure makes perfect sense, because the process surely involved an enormous amount of protocell reproduction cycles and subsequent generations of similar systems in constant interaction and transformation. As a result, there must have been a strong and very long sorting/ turnover among protocell families, or lineages, in their struggle for the material and energetic resources available on the surface of the primitive Earth. Furthermore, the limited nature of these resources surely made ecological and other types of competitive/cooperative relationships necessary, from early stages, for the long-term sustenance of the emergent phenomenon, taken as a whole.

Therefore, it is highly compelling to conceive the three main dimensions of life –physiology, ecology and evolution– unfolding together, though asymmetrically, during its actual origins. At the end of that process, the living phenomenon, realised in/by individual autonomous agents (prokaryotic cells—the major causal drivers of most biological processes), transcends any of those particular individuals, extending far beyond their spatial boundaries and lifetimes. In other words, becoming a living organism, right from the beginning, from the dawn of life, requires the collective effort of many previous (proto-)organisms, with which it shares a common historical path.

Acknowledgements Authors were supported by IAS-Research Group Grant IT1668-22 from the Basque Government, grants PID2019-104576GB-I00 and PID2023-147251NB-I00, funded by MCIU/AEI/https://doi.org/10.13039/501100011033 and FEDER/UE (for projects 'Outonomy' and 'Outagencies', respectively) and the John Templeton Foundation (JTF, Science of Purpose -- Grant No. 62220). This contribution improved thanks to helpful critical comments from two reviewers (Alejandro Merlo & Leonardo Bich) and the editors of the compilation (Arantza Etxeberria & Xabier Barandiaran).

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Chapter 6
Biological Autonomy and Reproduction

David Cortés-García

Abstract This chapter encompasses a discussion about the understanding of reproduction in the theory of autonomy, emphasizing the need to expand traditional theories of autonomous self-reproduction to account for interorganismal and ecological interactions. Drawing from recent contributions in the philosophy of biology, the chapter examines some of the limitations of self-reproduction as an endogenous process derived from self-production, highlighting cases such as sexual reproduction or symbiotic dependencies that illustrate the relational and interactive nature of reproduction. I then argue for an extended framework that integrates relational dependencies and distributed organizational processes.

Keywords Biological Autonomy · Interdependence · Symbiosis · Relationality · Self-Reproduction · Self-Maintenance · Material overlap

6.1 Introduction

Biological autonomy is a central concept in understanding living systems, which captures their capacity to self-maintain and regulate their own functioning. However, our growing knowledge on the interconnectedness and mutual dependencies of the living is calling for a rethinking of the concept of biological autonomy. The limitations of traditional formulations of autonomy have been highlighted, emphasizing that autonomy must account for interactive aspects beyond internally regulated self-organization (Aguilera and Di Paolo 2019; Moreno et al. 2008). In particular, this chapter explores how reproductive processes, far from being merely internal functions or outputs, often depend on dynamic interactions with other organisms, developmental scaffolds, and environmental cues. These observations challenge the prevailing ideal of autonomous self-reproduction and invite a reconceptualization

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X. E. Barandiaran and A. Etxeberria (eds.), *Outonomy*,
SpringerBriefs in Philosophy, https://doi.org/10.1007/978-3-032-05501-9_6

of reproduction within the organizational theories as a structurally dependent and ecologically embedded phenomenon (Etxeberria 2026, this volume).

Organizational theories of biological autonomy have traditionally subordinated reproduction to metabolic self-maintenance. However, several recent contributions have sought to incorporate reproductive functions into this framework. These include analyses of functional integration (Mossio et al. 2009; Saborido et al. 2011), organizational extended inheritance (Pontarotti 2015), intergenerational continuity (DiFrisco and Mossio 2020), reproductive individuality (Nuño de la Rosa et al. 2021), reproductive continuity (Etxeberria 2023), mutual dependencies (Etxeberria et al. 2023), reproductive agency (Nuño de la Rosa 2023) and reproductive traits (Cortés-García et al. 2024). These contributions have significantly advanced the discussion on how to integrate reproduction into organizational theories of biological autonomy. The perspective developed in this chapter is intended as a further contribution in this direction, by emphasizing the ecological and relational dimensions of reproductive processes, and exploring how these dimensions invite a reconceptualization of reproduction beyond the classical model of autonomous self-reproduction. By emphasizing the diversity of reproductive processes and their dependence on interactions within and across organisms, I argue that reproduction is not simply a capacity of autonomous individuals but a process that frequently exceeds and redefines the boundaries of individuality.

6.2 Autonomous Self-Reproduction

In the theory of autonomy, reproduction is understood as a second-order process, derived from the self-produced organization of the autonomous system. Within this framework, organization holds ontological primacy and is conceptualized as the determining factor of what constitutes a living being. Consequently, other processes such as reproduction or evolution are theorized as secondary, or second-order, processes, derived from autonomous self-organization. As Humberto Maturana and Francisco Varela explicitly state, “[reproduction] requires a unit that reproduces itself; this is why reproduction is an operation subsequent to the establishment of the unit and cannot enter as a defining feature in the organization of living systems” (Maturana and Varela 1973, p. 92 my translation).

In developing this framework, Maturana and Varela (1973, 1984) emphasized that the production of similar but topologically distinct systems depends on causes that derive from the internal self-organization of the unit that reproduces. They adopted the notion of “self-reproduction”, which they reinterpreted and adapted within their theory of autopoiesis. Prior to their work, the notion of self-reproduction had already been discussed in various fields, such as theoretical biology, cybernetics, and molecular biology, particularly in relation to self-replicating systems (see below). In the theory of autonomy, self-reproduction is defined as the process through which an autopoietic unit produces another unit with a similar organization. Importantly, the process of self-reproduction is coupled to the process of self-production, so that self-reproduction is an extension or a particular form of self-production and thus exclusive of autopoietic systems. Self-reproduction is contrasted with replication and copy fundamentally in that the mechanism for reproduction is not external to the system that is reproducing, but identical to it (Maturana and Varela 1973). Hence, reproduction remains entirely internal for the logic of autonomy: it presupposes an already constituted individual, and the causal elements involved in its realization are intrinsic to the system itself.

Further developments of the idea of autonomous self-reproduction emphasize the continuity of the self-produced organization beyond the lifespan of the individual system. Following the reasoning proposed by Maturana and Varela, reproduction is conceptualized in functional terms as a process through which the autonomous system produces similar units, thereby succeeding in maintaining its organization beyond the limits imposed by the decay of the precarious autonomous system (Ruiz-Mirazo et al. 2000, 2004). This view faces the challenge that reproductive traits, such as gametes, mating behaviors or reproductive organs, do not appear to contribute to the self-maintenance of the individual organism. In this sense reproductive functions seem to fall outside the organizational regime that define autonomy in its classical formulation. Two strategies have been proposed to resolve this tension. One appeals to higher-order entities, such as populations, species or ecosystems, as the relevant units whose autonomy is supported by reproduction (Mossio et al. 2009). The other refrains from invoking supra-organismic individuality and instead proposes that reproduction contributes to the continuity of organizational structures across generations. On this view, the autonomous system is not defined by the persistent identity of a single unit, but by the maintenance of a self-producing organization that transcends individual life cycles: “self-maintaining organization […] maintains itself also through reproduction” (Saborido et al. 2011, p. 16). In both cases, reproduction remains framed as a means to preserve organizational identity, either at a higher organizational level or over time.

Importantly, organizational approaches to *autonomous self-reproduction* differ significantly from previous and contemporary views on self-reproduction which center on the possession of a particular hereditary determinant that is theorized to ensure parent–offspring similarity and thus ground faithful inheritance. Examples include the program in von Newmann’s automaton theory, the germ plasm in Weismannism, the genetic program in Jacob and Monod’s view on molecular biology, and the replicator in Dawkins’ gene-eye view. These models conceive reproduction as the transmission of a pre-existing set of instructions, containing all the information necessary to produce similar entities, often overlooking the material and dynamic processes that drive development and reproduction. Thus, reproduction is reduced to the mere production of copies, overlooking the material and dynamic processes that drive development and reproduction. In brief, within these theories, self-reproduction is “self” in the sense that the reproducing individual is assumed to contain all the information necessary to produce a similar entity. The focus lies on the content of the set of instructions, rather than on the processes through which those instructions are interpreted and realized.

In contrast to these informational models, organizational theories conceive self-reproduction in fundamentally different terms. Rather than depending on the transmission of a pre-existing set of instructions, reproduction is understood as the result of an operational continuity between the reproducing and the reproduced systems. What is preserved across generations is not a code, but a mode of organization sustained through material and developmental processes.

A closely aligned view can be found in James Griesemer's notion of material overlap, which emphasizes the physical contribution of the parent organism to the formation of the offspring (Griesemer 2000). For Griesemer, reproduction entails the transmission not of symbolic content, but of developmental capacities grounded in material structures, such as cytoplasmic components, organelles, and even ecological elements that scaffold the ontogeny of the new individual (Griesemer 2014). This view reinforces the material and relational dimension of reproduction, shifting attention from copying to development. As noted by Saborido and colleagues (2011), the key distinction between Griesemer's view and autonomous self-reproduction lies in the level of abstraction: whereas material overlap highlights the intergenerational transmission of developmental potential, autonomous self-reproduction focuses on the preservation of a specific organization. Both, however, depart from reducing reproduction to replication and contribute to expanding the theoretical framework in which reproduction can be understood.

In short, the concept of autonomous self-reproduction encompasses the idea that the main causal factors involved in the production of offspring rely on the internal or endogenous properties, materials and processes of the autonomous self-maintaining individual. The theory of autonomous self-reproduction acknowledges the role of external interactions, but it tends to subordinate them to the internal, self-maintaining organization of the individual. The next section reviews how reproduction needs to be understood beyond the individual.

6.3 Interorganismal Relations in Reproduction

Reproductive processes often involve structural dependencies, mutual regulation, and causal entanglements between organisms, such that the reproduction of one system depends constitutively on its relation to others. These cases provide a basis for re-evaluating the adequacy of classical models of biological autonomy, and for advancing towards a form of *outonomous* reproduction.

Sexual reproduction is one of the most paradigmatic cases of relational dependence in biology. Despite significant differences between phylogenetic groups, all cases of sexual reproduction require the entanglement of materials originating from two different organisms (except for the rare cases of self-fertilization). The degree of physical interaction between organisms during reproduction varies widely, including nucleic, cytoplasmic and/or morphological structures. While this fact is widely recognized, its conceptual consequences for theories of autonomy are often overlooked. It suggests that, in some occasions, reproduction involves the integration of two operationally distinct systems, whose coordinated interaction gives rise to a new system with emergent interorganismal properties (Cortés-García et al. 2024).

Singularly, viviparous modes of reproduction involve an extended period of internal incubation and therefore a closer relationship between the gestating individual and the offspring. A particularly well-studied example is eutherian pregnancy, which a dynamic interplay between maternal and embryonic systems, mediated by the placenta. Far from acting as a passive container, the gestating organism engages in a co-regulated physiological process in which both systems influence each other's development, metabolism, and immune function (Wagner et al. 2014; Erkenbrack et al. 2018). In these cases, the reproductive event is not a discrete act of generation, but a transient configuration of mutual dependence, where the classical boundaries of individuality are blurred. Recent work suggests that pregnancy exemplifies a form of reproductive entanglement where the developing organism not only relies on but also modifies its maternal environment, creating an interdependent structure that challenges traditional notions of biological individuality (Nuño de la Rosa et al. 2021), agency (Nuño de la Rosa 2023) and autonomy (Etxeberria et al. 2023). This view highlights how processes of self-maintenance and reproduction become entangled within broader ecological and physiological networks.

Such analyses contribute to a reconceptualization of reproduction as an interactive system of physiological and developmental mutual dependencies, rather than as a mere transfer of genetic material between discrete individuals. Kepa Ruiz-Mirazo and colleagues (2000) have acknowledged that sexual reproduction challenges classical models of reproduction, since both parent organisms contribute organizationally, not just genetically, to the formation of the new system. James DiFrisco and Matteo Mossio (2020) go further, conceptualizing these events in terms of fusion and fission of autonomous systems, where individuality can be interpreted as a relational and emergent property. In this light, reproductive processes appear less as operations performed by individuals, and more as transformations of individuality itself, resulting from structured interactions between already organized, but interdependent, living systems. This underscores the need to rethink reproductive dynamics as emergent processes, shaped by interactions between distinct yet relationally intertwined autonomous systems.

While sexual reproduction illustrates how reproduction can require the integration of multiple individuals from the same species, symbiotic systems reveal that such integration often crosses species boundaries. In recent years, research on holobionts (i.e., integrated units composed of a host and its associated microbial communities) has transformed our understanding of biological individuality. Yet their implications for reproduction remain underexplored. In many cases, successful reproduction of the host is not possible without the active participation of its symbionts. These associations are not merely physiological or ecological, but developmentally and reproductively constitutive (Chiu and Gilbert 2015). For instance, in mammals, maternal microbial communities play a crucial role in shaping the immune system of the offspring during and after birth and are also fundamental for key physiological processes such as digestion. Similarly, certain insects, such as aphids, are entirely dependent on bacterial symbionts for the biosynthesis of essential nutrients that enable successful reproduction. Without these symbionts, reproduction and survival would be severely compromised. Development and reproduction are thus dependent on interspecies communication (Gilbert et al. 2012). Such cases suggest that reproduction is not the isolated activity of a single organism, but rather it should be understood as a distributed process involving reciprocal scaffolding between structurally distinct systems. The reproductive unit, in these contexts, is not an autonomous individual in the classical sense, but a relational configuration, dynamically sustained through multispecies cooperation. This challenges accounts of autonomy that assumes the self-contained closure of the reproductive process.

Moreover, this pattern is not limited to metazoans. Symbiosis plays a foundational role across the tree of life, from unicellular eukaryotes to bacteria and viruses. Reproductive processes in many microbial systems rely on cross-species interactions, including horizontal gene transfer, endosymbiotic integration, and transient cooperative associations. These dynamics facilitate adaptation, lineage emergence, and metabolic innovation. For instance, the integration of viral genetic material into bacterial genomes demonstrates how reproductive events can depend on cross-species interactions. In addition, some unicellular eukaryotes reproduce more efficiently or acquire key metabolic capabilities by harboring symbiotic bacteria or by engaging in temporary associations with other microorganisms (Dupré and O'Malley 2013).

In addition to this, Lynn Margulis and Dorion Sagan (1986) have proposed a scenario where the emergence of sexual reproduction is deeply linked to ancient symbiotic events that shaped early eukaryotic life. They suggest that the process of endosymbiosis that led to the evolution of the eukaryotic cellular structure not only originated mitochondria and plastids but also laid the groundwork for sexual processes, as the exchange and recombination of genetic material became central to maintaining the stability and adaptability of these newly integrated systems. Sexual reproduction is thus understood as an evolutionary innovation rooted in relationality and cooperation, where genetic recombination, whether through horizontal gene transfer, symbiosis, or sexual fusion, emerges from processes of interaction, fusion, and exchange that challenge traditional views of individuality and autonomy.

The organismal interactions and co-dependencies portrayed here illustrate how the reproductive unit does not necessarily align with the self-maintained biological individual, posing important challenges to existing notions of autonomous self-reproduction.

6.4 Outonomous Reproduction?

I have sought to illustrate some limitations of the notion of autonomous self-reproduction, minimally conceived as a natural result of the endogenous metabolic activity of a living cell, which grows and produces another topologically distinct but organizationally equivalent individual. As shown in the previous section, in many cases, the causes of reproduction are not solely endogenous but also dependent on exogenous interactions, which can take various forms, such as the necessity of sexual partners for mating, parent–offspring dynamics during care and development, host-microbiome relationality, and also broader symbiotic associations.

To adequately account for these phenomena, we need an organizational notion of reproduction that broadens the focus beyond the self-maintaining individual, incorporating inter-organismal relations, while still remaining sensitive to internal organizational constraints. Such an approach would recognize that reproduction is not merely the outcome of an autonomous system's internal processes but often emerges from the interaction between internal and external organizational dynamics in heterogeneous and interdependent systems (Bich and Bechtel 2025, this volume). By integrating these interorganismal and environmental factors, this perspective can provide a more comprehensive understanding of reproduction as a process embedded within both ecological and social networks, where the viability and continuity of life depend on interconnected systems rather than isolated individuals. The concept of outonomous reproduction has the potential to capture those reproductive processes that arise from mutual scaffolding, material entanglements, and coordinated interaction.

This reconceptualization finds important precedents in earlier work within the organizational tradition. Almost two decades ago, Moreno and colleagues (2008) argued, in more general terms, that autonomy cannot be reduced to internal self-organization alone. They distinguished between constitutive and interactive processes, emphasizing that the latter, often dismissed as secondary, are in fact essential for the maintenance of a system's identity. In their words, “autonomy requires more than self-organization or self-maintenance” (Moreno et al. 2008, p. 312). The present proposal extends this insight by showing how, in the case of reproduction, such interactive processes are not merely supportive of autonomy but constitutive of the very possibility of its transmission and transformation.

This project of elaborating a theory of autonomous reproduction finds promising conceptual tools in the formulations of the continuity of material organization discussed earlier (see Saborido et al. 2011; DiFrisco & Mossio 2020). Although often underexplored, this notion offers a potential starting point for integrating the metabolic and physiological dimensions of self-production with the ecological, diachronic and evolutionary aspects of reproduction. To achieve this, the concept of organizational continuity must adopt an interactive and distributed view that can encompass scaffolded reproduction, multispecies consortia and relations of interdependency in reproduction. This implies that the concept of organizational closure might not be a universal criterion for defining the limits of continuous organization. In this view, what persists is not a self-constructed organization, but a network of functional relations sustained and transformed across bodies, environments, and temporal scales. This perspective would preserve the organizational account's emphasis on functional integration, while overcoming some of its internalist assumptions. This idea opens the possibility of understanding different reproductive phenomena as constitutively influenced by environmental and social interactions (Martínez-Quintero and Rodriguez-Muguruza 2025, this volume).

The extended and distributed proposal for an outonomous view of reproduction sketched here aligns with a view of life that shifts away from focusing solely on individual organisms and instead emphasizes global processes. In this perspective, reproduction is understood as a collective and community-wide property where reproductive agency is distributed (Etxeberria 2023). Outonomous reproduction is not solely the re-production of form, but also the maintenance of relational continuity across generations, where what is reproduced is not identity but a network of historically stabilized dependencies. In this sense, outonomous reproduction is not a departure from the theory of autonomy, but a step toward its relational reformulation.

6.5 Conclusions

In this chapter I have tried to summarize some of the problems that our current knowledge about biological reproduction poses for the notion of autonomous self-reproduction. I have outlined different possible responses to these challenges, aiming to foster further discussions on the role of reproduction in biological theories and how the notion of self-produced autonomy might be expanded or reformulated to reflect the interactive and relational nature of living phenomena and reproductive processes. The perspective sketched here questions certain aspects of the theory of autonomy and invites us to consider an extended or distributed view of life and reproduction.

Acknowledgements I acknowledge funding from IAS-Research group funding IT1668-22 (Basque Government); grant PID2023-147251NB-I00 "Outagencies", funded by MCIU/AEI/ https://doi.org/10.13039/501100011033 and FEDER/UE; a predoctoral contract granted by the University of the Basque Country [PIF-2020]; and grant PID2021-127184NB-I00 “Metaphysics of Biology”, funded by MICINN.

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Chapter 7
Autonomy and Alienation in Menstrual Health

Alejandra Martínez-Quintero and Ainhoa Rodríguez Muguruza

Abstract This chapter redefines autonomy in bioethics by foregrounding menstrual agency as a relational and embodied capacity, rather than an isolated expression of individual choice. It argues that menstrual health has been reduced to reproductive function, excluding the psychological, emotional, and social dimensions of menstruators' lived experience. Despite being reduced and overlooked, the way menstrual health intersects with emotional, social, and cultural dimensions reveals that even in health, autonomy can be experienced as both vulnerability and agency. Drawing on a triadic approach to ailments and the enactive concepts of autonomy, agency, and precariousness, the chapter reconceptualises menstrual well-being as a shared ethical and social concern. In doing so, it challenges dominant notions of autonomy and calls for structural transformations that support menstruators in reclaiming agency over their menstrual lives.

Keywords Menstrual health · Autonomy in bioethics · Enactive agency · Feminist phenomenology

7.1 Introduction

In 2022, the World Health Organisation redefined menstrual health beyond hygiene, recognising it as a physical, emotional, and psychological process integral to overall well-being. Despite this progress, menstrual health has often been narrowly framed around reproduction. While the cycle prepares the body for pregnancy, it also

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Both authors contributed equally to the development of this article. The order of authorship reflects internal decisions within the collaboration and does not imply a hierarchy of contribution.

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X. E. Barandiaran and A. Etxeberria (eds.), *Outonomy*,
SpringerBriefs in Philosophy, https://doi.org/10.1007/978-3-032-05501-9_7

regulates immune function (Howes 2010), metabolises fats and carbohydrates, and supports muscular, skeletal, gastrointestinal, hepatic, and neural systems (Plant and Zelesnik 2015). Defining menstrual health solely through fertility oversimplifies its systemic complexity (Jasienska 2013).

This paper explores how autonomy can be conceptualised and exercised by menstruators within medical contexts, where menstrual health is often pathologised or dismissed. The principle of autonomy in bioethics was created to protect patients from medical practices that ignore their agency. However, it frequently assumes autonomy as rational, individual, and disembodied (Paul et al. 2003), assumptions that do not reflect the lived experiences of autonomy. We argue that autonomy is not undermined by bodily vulnerability, but constituted through it. Drawing on the triadic approach and enactive theory, we conceptualise autonomy as inherently precarious: it is sustained through ongoing bodily and environmental negotiation. This framework allows us to reconceive the menstrual cycle not as a disruption to autonomy but as an active, ongoing process through which agency is enacted.

7.2 Rethinking Autonomy in Bioethics

Autonomy is foundational in bioethics, but often framed as rational, individual, and context-free (Casado da Rocha and Etxeberria 2012). This narrow view fails to capture how real-life decision-making in health is shaped by bodily states, lived experience and social conditions. Health decisions are not made from a disembodied ideal, but from concrete bodies, with specific vulnerabilities. This is particularly relevant when autonomy in health decision-making seems more challenging, like during illness or physiological conditions like pregnancy, breastfeeding, or the hormonal fluctuations of the menstrual cycle.

Addressing concrete vulnerable bodies sheds light on how the traditional view of autonomy misses that every human life is autonomous and at the same time precarious. Recognising this shifts the analysis from idealised independence to enactive, embodied agency. This section draws on Casado da Rocha and Etxeberria's (2012) triadic model of health, combined with insights from enactive and organisational theories, to argue for understanding autonomy as inherently precarious, socially embedded, and continuously enacted by the agent. This approach offers a nuanced account of agency in clinical contexts, attending to the material, affective, and normative dimensions of lived experience. Integrating the sense of agency with this model will help to explain why menstrual embodiments are often seen as pathological rather than integral to menstruators' agency.

7.2.1 Idealised Autonomy and the Triadic Approach

Bioethics is commonly guided by four principles: respect for autonomy, beneficence, non-maleficence, and justice (Casado da Rocha and Etxeberria 2012). Respect for autonomy affirms a patient's right to make informed decisions about their health. However, Casado da Rocha and Etxeberria argue that treating autonomy as a formal, context-free right, something a patient either has or lacks, fails to reflect the realities of illness. Instead, they propose understanding autonomy not as a fixed right to be granted, but as a capacity, to make decisions, consent to treatment, and act meaningfully, that can be eroded by bodily vulnerability.

They argue that both autonomy and health must be understood across three interrelated dimensions: physiological, subjective, and social. Hence, they propose a triadic model to understand health conditions by distinguishing between disease, illness and sickness as the physiological, subjective and social aspects of ailments. For example, diabetes as a *disease* is defined by the objective measures that signal insulin resistance, such as elevated blood glucose levels. As subjectively lived, i*llness* captures the individual's experience of diabetes, such as shivering during hypoglycemia. Finally, as socially lived, s*ickness* describes how diabetes is recognised and responded to by others, such as when peers acknowledge the patient's impaired functioning.

The triadic approach shows that autonomy cannot be taken for granted within illness, as each dimension, biological, experiential, or social, can compromise the capacity to act autonomously. This critique suggests that even when bioethical protocols are followed, such as providing adequate information, patients may still experience vulnerability rather than the capacity to act autonomously. This layered view challenges the idealised image of the independent, rational patient and instead presents autonomy as inherently interdependent. Recognising this interdependence shifts the focus from autonomy as an individual possession to a collective responsibility, sustained across medical, social, and relational contexts (Urdangarin and Umerez 2026, this volume).

7.2.2 Using Enactive Concepts: Autonomy, Precariousness and Sense of Agency

Building on the triadic model, enactive and organisational theories can deepen our understanding of the vulnerability of autonomy by framing it as a core property of living systems. Here, a*utonomy* refers to a living system's capacity to self-maintain and self-organise (Moreno and Mossio 2015; Di Paolo et al. 2017). Living beings are operationally closed and yet thermodynamically open to material and energetic exchanges. This balance between defining an identity while remaining open illustrates the enactive notion of *precariousness.* Within enactive theory, the concept of *precariousness* carries three related meanings (Di Paolo and Beer 2023): the fragility of the processes that realise operational closure, the intrinsic fragility of the system as a whole, and the vulnerability associated with thermodynamic openness. Here, precariousness refers to a broader sense of *embodied vulnerability*.

Unlike idealised or abstract models of autonomy, an account rooted in embodied vulnerability portrays living beings as constantly navigating this tension, neither fully independent nor fully determined by their environments. This understanding of precarious autonomy has specific implications for how we approach menstrual health, an area where bodily vulnerability is often interpreted as incapacity rather than a dimension of agency. From an enactive view, it is precisely the embodied vulnerability that has the potential for *agency*. The intrinsic tension to sustain life under precarious conditions, gives rise to meaning and action (Di Paolo 2018). Even when regulation falters, the potential for agency remains, as long as autonomy endures. In this sense, precarious conditions, understood as constraints for agency are not always limiting; they can also enable action. When agents interpret precariousness as navigable rather than paralysing, their scope for agency expands. This interpretive stance, what enactivists metaphorically call “surfing” precariousness, allows vulnerability to become a source of agential depth rather than a barrier to autonomy.

Embodied vulnerability, applied to the triadic approach, can manifest across metabolic, sensorimotor, and social levels: from maintaining biological processes (metabolic), to the fragility of habits and skills (sensorimotor), to the breakdown of social coordination, such as disrupted conversations (De Jaegher and Di Paolo 2007). These layers illustrate how autonomy is not a stable trait but a dynamic, precarious process shaped by bodily, cognitive, and relational factors. This view aligns with the triadic model of autonomy in illness, which frames agency as emerging through the interaction of embodiment, social embeddedness, and subjective interpretation. It also resonates with enactive and organisational accounts that distinguish between autonomy as a capacity and agency as enactment (Rubel et al. 2021). Because agency, in this framework, operates across normative domains, biological, sensorimotor, and social, conflict often follows. Yet even when these tensions arise, the underlying capacity for autonomy endures. Agents continue to act within and through these constraints, sometimes in ways that contradict long-term well-being. Autonomy, therefore, remains precarious and subject to limitation, but so long as it persists, the potential for agency remains.

7.3 The Alienation of the Menstrual Cycle

Understanding autonomy through enactive and triadic frameworks deepens what it means to respect autonomy in contexts of illness and reveals the particular challenges faced by non-normative bodies, including menstrual bodies. These are bodies that diverge from dominant biomedical or social norms, whether through gender, reproductive variation, or other physiological differences (Lugones 2007). Menstrual health exemplifies how physiological symptoms, subjective experience, and social stigma intersect to shape agency. Pain, irregularity, and taboo can distort self-understanding and foster alienation.

If illness compromises autonomy by weakening agential capacity, then alienation from one's body has similar effects. Reclaiming agency in menstrual health begins with acknowledging and reintegrating those embodied experiences that have long been marginalised or medicalised.

7.3.1 Alienation and Reclamation: The Menstrual Cycle and the Lived Body

Despite being a natural process, menstruation has long been alienated, framed as disordered, uncontrollable, or pathological. This framing undermines agency by treating menstrual experience as something to manage or conceal rather than as an integral aspect of embodied life. Feminist phenomenologists like Iris Marion Young (2005) argue that scientific objectivity reinforces this alienation by reducing menstruation to biological facts and separating it from lived experience. Medical discourse often limits menstruation to reproduction, ignoring its broader connections to health, well-being, and autonomy.

Even when biological facts are known, such as hormonal fluctuations before menstruation, menstruators are rarely supported in managing the emotional, energetic, or social challenges that follow. Menstrual experience remains largely unacknowledged, while expectations of composure persist despite limited access to affordable products, private facilities, and comprehensive education. The inability to rinse a menstrual cup at work or to sit through an exam while in pain exemplifies how public systems fail to accommodate menstrual needs. These conditions reflect a medical model that treats menstruation as a problem of biology rather than a meaningful, lived experience.

Simone de Beauvoir's existential feminism deepens this critique by showing how agency is shaped through reclaiming subjectivity in the face of bodily objectification. Social forces, such as the male gaze or early sexualisation during puberty, position menstruators as passive objects of attention (Young 2005; Bergoffen 2000), distancing them from bodily ownership. For Beauvoir (1949), reclaiming agency requires owning the lived body and its transitions, including menarche.

Integrating menstrual experience into one's sense of self challenges the dominant view of the body as merely biological. It is a process of reclaiming meaning, resisting objectification, and navigating conflicting norms. Agency, in this light, emerges not by denying bodily experience but by actively incorporating it, through cycles, discomforts, and cultural tensions, into one's autonomous self.

7.3.2 Menstrual Health as a Shared Responsibility

While reclaiming one's body is personal, Beauvoir's existential ethics reminds us that agency is also a shared responsibility. In *The Ethics of Ambiguity*, she argues that true freedom requires working to liberate others from oppression (Bergoffen 2000). This is especially relevant for non-normative bodies, those that deviate from dominant medical, social, or cultural norms, such as menstruators with chronic conditions, disabilities, neurodivergence, or cyclical variability. These individuals often occupy the margins of care and social recognition, requiring both ethical and epistemic attention.

Beauvoir's view challenges the bioethical tendency to treat autonomy as an individual right. Instead, autonomy should be seen as fragile, embodied, and relational, shaped by social, institutional, and medical systems. Respecting autonomy, particularly in the context of menstrual health, means more than avoiding coercion; it demands actively enabling meaningful agency. Stigma, under-researched conditions, and fragmented care often constrain menstruators' ability to act as full agents of their health.

Approaching menstrual health as a shared responsibility means recognising that autonomy is co-constructed, developed within networks of care, trust, and support. Menstrual health should be central to preventive and primary care, including improved research, broader diagnostic models, and equitable access to resources. Yet medical care alone is insufficient. Agency is not merely the capacity to choose but the ability to act in ways that reflect one's embodied self-understanding. This capacity is vulnerable, especially in the context of menstrual pain, emotional fluctuation, and social stigma, and must be supported when it falters. Respecting autonomy, and hence supporting agency, thus means redistributing responsibility across healthcare systems, institutions, and communities. Framing menstrual health in terms of agency, rather than choice or compliance, allows us to respond to its relational and precarious nature.

Ultimately, integrating these insights into menstrual care reshapes expectations and practices. Together, they foster environments where bodily awareness and agency can flourish. This socially sustained view of autonomy sets the stage for the next section, where we move from ethical framing to practical application, offering a redefinition of menstrual health that centers agency and embodied meaning.

7.4 Reinterpreting Menstrual Health

Building on the earlier reframing of agency as relational and embodied, menstrual health should be seen as an interdependent phenomenon encompassing physiological processes, subjective experience, and sociocultural structures. If agency is a fragile, collectively sustained capacity, menstrual health must be understood not merely in biomedical terms but as a dimension of embodied agency. This challenges the conventional reduction of menstrual health to reproductive function (Clough 2002) and opens space to examine how practices, awareness, and relations support or undermine agency.

Autonomy must be redefined, not as detached self-governance but as a capacity shaped by biological rhythms, social connections, and material realities. Menstrual health, then, is not a fixed state but a dynamic lived condition through which agency is enacted. Rather than an entirely new paradigm, this is a reorientation: menstrual health is a key site where bodily knowledge, social norms, and medical discourses converge. It is deeply tied to the enabling conditions of relational autonomy.

7.4.1 Reframing Knowledge on Menstrual Health

To address menstrual health philosophically is to center the body as shaping and enabling agency. Autonomy is enacted within physiological, relational, and structural contexts. Menstrual health exemplifies this embeddedness, not as biological regularity but as a lived and negotiated state shaped by internal cycles, experiential knowledge, and social validation. Iris Marion Young (2005) highlights how menstrual alienation stems from scientific reductionism that renders bodies measurable but separate from lived experience. This framing casts menstrual bodies as unruly or deficient, interpreting deviations from narrow norms as dysfunction. Such objectification fragments self-understanding, discouraging embodied interpretation.

A phenomenological approach restores the body as a site of meaning and knowledge. Menstrual variability, fluctuations in cycle length, hormones, energy, and emotion, should not be pathologized. Biomedical indicators like regularity or balance cannot serve as absolute norms. Irregularities may reflect adaptive physiological responses to environmental, emotional, or metabolic change. Health here is not deviation's absence, but the ability to negotiate embodied rhythms in context. This reframing aligns with critiques of reductive autonomy. Just as autonomy is more than individual decision-making, menstrual health is more than stable biology (Alvergne et al. 2018). It emerges through physiological dynamics and the social, epistemic structures that shape bodily interpretation. We must resist reducing menstruation to isolated systems and instead recognise it as systemic and co-regulating: affecting cognition, emotion, immunity, and metabolism. Simone de Beauvoir's existential feminist ethics deepen this perspective. Reclaiming the body from objectification is crucial to reclaiming agency (Beauvoir 1949). Menstrual reclamation involves recognising the cycle as a meaningful, patterned embodiment, not a disruption. This requires cultivating awareness that treats fluctuations as informative. Menstruation can thus be a source of insight, revealing changing needs and capacities.

Yet this awareness is not solitary. The triadic model of disease, illness, and sickness reminds us that bodily meaning is both personal and collective. Menstrual cycles are interpreted through experience and cultural scripts, medical norms and institutional frameworks. Recognition, by clinicians, educators, and policymakers, is critical for legitimising menstrual knowledge. Understanding menstrual health as a dynamic capacity thus entails confronting epistemic injustice and structural neglect. This reconceptualisation redefines both health and knowledge. Health becomes the body's capacity for adaptation and meaningful interaction with its cycles, and knowledge arises from lived, reflective engagement (Menatti 2026, this volume). Menstrual health becomes an interpretive, context-sensitive process through which bodies are understood and navigated, supporting a more expansive form of agency.

7.4.2 The Role of Bodily Self-Awareness in Menstrual Health

Recognising menstrual health as a dynamic capacity centers bodily self-awareness in the practice of health and autonomy. Health is not static conformity but ongoing responsiveness to internal and external conditions. Through reflective attention to symptoms, shifts, and patterns, menstruators cultivate embodied knowledge: a situated understanding of their cycles essential for self-care and legitimacy. Biomedical models often dismiss subjective reports as anecdotal, privileging quantifiable data. Yet feminist theorists and health advocates argue that experiential knowledge, built over time, offers vital insights. Menstrual cycles affect cognition, mood, metabolism, and energy in context-sensitive ways. For instance, some feel more resilient during ovulation, while others experience premenstrual irritability or clarity (Pels 2022; McEvoy and Osborne 2019). These variations highlight the complexity of hormonal embodiment and the inadequacy of static clinical norms.

Reproductive endocrinology confirms substantial inter- and intra-individual variation (Jasienska 2013), complicating the search for universal biomarkers. This ambiguity reinforces the epistemic value of self-attunement. Variability fosters insight, not uncertainty. Self-awareness is not indulgence; it is an interpretive skill developed through embodied engagement. Feminist phenomenology insists that the body is a site of meaning-making (Young 2005; Bergoffen 2000). This view elevates menstruators' insights as foundational to autonomy. Menstrual health thus emerges as both biologically mediated and phenomenologically lived. It integrates hormonal rhythm with reflective sense-making (Rodriguez-Muguruza 2023). Attunement allows behaviour and care to align with embodied states. Agency, then, resides not in abstraction but in navigating bodily transformation. Awareness is not just preliminary to action; it sustains it. Menstrual knowledge, built through bodily dialogue, reveals agency as situated and responsive.

7.4.3 Integrating Menstrual Knowledge into Agency

If menstrual health is a dynamic, embodied lived experience, then agency must include the cyclical and contingent. Integrating menstrual knowledge strengthens the relationship to the body, enabling intentional adaptation. This does not imply control or optimisation but learning to live responsively within physiological flux.

The concept of a dynamic menstrual health encompasses both physiological rhythms and the systems through which these are interpreted and supported. Attunement lets menstruators adjust expectations and behaviours, for instance, recognising increased sensitivity in the premenstrual phase may guide care and interaction (Rodriguez-Muguruza 2023). This is not about avoiding symptoms but cultivating adaptive agency attuned to lived bodily conditions. Reclaiming autonomy also requires collective transformation. Menstrual health must be affirmed through education, research, and clinical practice. Healthcare systems should treat the cycle as a dynamic biomarker, using symptoms and patterns as indicators of broader health, as emerging research suggests (Rosen et al. 2024; Prior 2021). This must be done without normative assumptions, respecting variability and individual context.

Policy investment is essential to overcome menstrual marginalisation in medical research and care. This is not a novel framework but a return to what is already lived: menstrual health as intelligible, situated knowledge. Validating menstrual experience fosters autonomy and justice. By reclaiming menstruation as a source of embodied insight, we resist abstraction and embrace agency as a responsive, evolving practice.

7.5 Conclusion

Understanding autonomy as embodied vulnerability, as an inherently precarious yet potentially agentive condition, enables menstruators to assert meaningful agency over their health. This perspective challenges the common reduction of menstrual health to reproductive function alone. Rather than viewing autonomy as isolated self-mastery, it emerges from the dynamic interplay of biology, relationships, and material realities. Scientific reductionism often pathologises menstruating bodies, estranging individuals from their embodied experiences. A phenomenological approach counters this by positioning the body as a site of knowledge, where menstrual variability is natural, not deviant. Health, then, is not static but an ongoing negotiation of bodily rhythms within lived contexts, defying rigid biomedical norms.

Bodily self-awareness is central, emerging from engagement with cyclical patterns and shifts. This awareness empowers adaptive responses and challenges norms that dismiss subjective menstrual experience, making these insights foundational to autonomy. Integrating menstrual knowledge means embracing the cyclical nature of embodied life and adapting care to fluctuating needs. This calls for healthcare and policy changes that affirm menstrual health as central to well-being, requiring personalised and context-sensitive support. Ultimately, menstrual health is a vital site of knowledge and agency, involving ongoing negotiation rather than correction. Embracing menstrual variability as part of autonomy challenges marginalisation and promotes more just, humane care. Living responsively within bodily rhythms reclaims bodily autonomy as relational and deeply human.

Acknowledgements AMQ and ARM acknowledge funding from IAS-Research group funding IT1668-22 (Basque Government) grant PID2019-104576GB-I00 "Outonomy" funded by MCIU/

AEI/10.13039/501100011033. AMQ was also funded by a predoctoral grant from the University of the Basque Country (PIF18/163). ARM also from the 'Metaphysics of Biology' project [PID2021-127184NB-I00].

This research was supported by the Basque Government [IT1668-22], grants PID2019-104576GB-I00 for project Outonomy and PID2023-147251NB-I00 for Outagencies funded by MCIU/AEI/10.13039/501100011033 and FEDER/UE, and the 'Metaphysics of Biology' project [PID2021-127184NB-I00].

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Part III
The Psychic Self and Its Environment

Chapter 8
Process and Relational Ontology in Enactive Psychiatry

Enara García

Abstract This chapter examines mental disorders from an enactive perspective. It explores two key ontological claims—the processual and relational nature of cognition—and their implications for our understanding of mental disorders. Rather than viewing them as isolated brain disorders, mental disorders are presented as developmental sensorimotor trajectories that are shaped by embodied interactions and social contexts. It highlights the dynamic interplay between an individual's autonomy and their social environment in the emergence of mental disorders.

Keywords Mental disorders · Enactive cognition · Intersubjectivity · Process ontology · Relational autonomy

8.1 Introduction

Contemporary understanding of mental health has evolved significantly, moving beyond the notion of the self-sufficient autonomous individual. It now encompasses a more holistic view that recognizes the intricate interplay between personal well-being and the broader social, environmental, and relational contexts in which individuals live. This perspective emphasizes that mental health is not solely a matter of individual resilience or autonomy, but is deeply influenced by the quality of our relations with others, our communities, and the environments we inhabit.

In recent years, enactive cognition theories have garnered growing interest as a relational framework that transcends internalist, individualist, brain-centered and biomedical models of mental health (de Haan 2020; Maiese 2022; Nielsen 2023). One of the main contributions resides in the acknowledgement that mental processes –and therefore mental disorders– are scaffolded by processes that extend to the sociomaterial environment. It challenges prevalent dualisms between mind and body, or physiology and psychology and promotes viewing autonomous individuals as embodied, situated and ecological agents. Accordingly, the enactive approach

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X. E. Barandiaran and A. Etxeberria (eds.), *Outonomy*,
SpringerBriefs in Philosophy, https://doi.org/10.1007/978-3-032-05501-9_8

conceptualizes mental disorders as phenomena emerging from the dynamic interplay between the agent and its environment, thereby recognizing the interconnectedness, mutual dependence, and multiscale embeddedness of psychiatric phenomena.

The aim of this chapter is to delve into two ontological principles that ground enactive psychiatry, its processual and relational ontology,[1] and clarify their relevance to better understanding psychiatric conditions.

8.2 Process Ontology

Philosophy of mind and psychiatry has long exhibited a static bias. The cognitivist framework, which was dominant in the 90s, viewed the mind as a series of discrete, static mental states, each generated by decomposable cognitive modules, viewing mental disorders as faulty or malfunctioning mental states (e.g., faulty beliefs in schizophrenic delusions). The same static bias is present in current models, such as the DSM, which classifies disorders based on fixed symptoms, or the biomedical model, which attributes them to specific brain dysfunctions. All these approaches have neglected the temporal course, diachronic character, and inherent dynamics of mental disorders. In contrast, the enactive perspective rejects this static view of the mind and adopts a process-oriented framework, emphasizing the dynamic nature of mental activity as processes that unfold in time, have a particular trajectory, and produce cumulative changes (Vintiadis 2022). Cognition is viewed as emerging from the regulation of organism-environment interactions, constituted by interactive processes that encompass the brain-body-environment system. Change, thus, is considered a fundamental property of cognition rather than a mere accident.

The enactive framework, drawing from organizational approaches in biology, views living organisms as self-producing autonomous entities that maintain their identity under precarious conditions (Varela et al. 1991, 2017). Autonomy extends beyond the biological (metabolic) domain to include sensorimotor and intersubjective dimensions (see Virenque 2026, this volume). Sensorimotor autonomy comes from networks of habits that endow the agent with adaptive behavior (Di Paolo et al. 2017), while intersubjective autonomy arises from social interactions, where individuals co-construct shared meanings, emotions, and collective identities (Di Paolo et al. 2017, 2018). The individual is thus constituted and traversed by normative processes that occur across these multiple domains of autonomy, often in tension with one another (García and Barandiaran 2024; Thompson and Varela 2001). Cognition involves the adaptive management of this plurality of normative tensions across the organic, sensorimotor and intersubjective domains, which are functionally coordinated at different timescales (e.g., the tension between biological hunger, cutlery skills and social manners in a formal dinner). This perspective rejects reductionism, by understanding domains of autonomy not as discrete levels that can be reduced

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[1] Here, ontology refers not to metaphysical assumptions about ultimate reality, but to the objects of specific sciences (i.e., cognitive science, psychology, psychiatry).

to their isolated components, but as processes that maintain each other dynamically across different timescales. The dynamic interaction between local processes of a system leads to emergent processes that, in turn, exert a "global-to-local" influence on those elements (Thompson and Varela 2001).

Similarly, mental disorders can be understood as emergent, organized wholes constituted by interacting processes across organic, sensorimotor, and intersubjective domains. This idea is also captured by the concept of "Dynamic Gestalt Patterns"— a set of interrelated factors that, while not individually necessary, collectively define a psychiatric disorder (Gallagher 2024). These complex, multi-layered feedback systems do not follow a linear cause-effect model but operate through organizational non-linear causality (Gallagher 2022; de Haan 2020). Changes in one part of the pattern influence and modify other parts, resulting in a constantly evolving, integrated whole. The apparent stability of mental disorders is, therefore, not a fixed trait of individuals but a temporary outcome of their dynamic self-organization.

One consequence of this view is that mental disorders are closely tied to the historical and developmental processes of individuation of the person. They are not external entities that can simply be removed from the individual; rather, they are ways in which the person is organized. This explains the self-illness ambiguity often seen in mental disorders —the difficulty of distinguishing between an individual's sense of self and the symptoms of the condition (e.g., identifying with negative thoughts in depression or manic states in bipolar disorder). In other words, they involve disturbances in the sense of self. Therefore, by shifting our focus from viewing individuals and selves as fixed and fulfilled to exploring their individuation process and becoming, we can better grasp the temporal asymmetry and path-dependence of mental disorders. Their progression over time—e.g., emergence, recovery, relapse, and chronicity—is not just a feature of traditionally recognized developmental disorders but is integral to all mental conditions. Plaintly said, I suggest that not only those traditionally classified as developmental disorders are indeed developmental.

One way of making sense of this path-dependence is through Piagetian mechanisms of sensorimotor equilibration (Di Paolo et al. 2017). The development of new skills and habits occurs through a dynamic equilibration between integrating new experiences into existing cognitive and sensorimotor schemas and adapting these schemas to accommodate new experiences. While developmental trajectories remain flexible, they also exhibit a diachronic channelling of possibilities within the broader space of behavioral possibilities. As habits and sensorimotor structures stabilize, they constrain future developmental paths by making some coping mechanisms more accessible while rendering others less likely. This form of habit stabilization can be viewed as the *character* of the person, that is an idiosyncratic cognitive, affective and behavioral style that marks a distinct personal identity. A crucial point here is that habitual interaction styles imply unique vulnerabilities, which predispose individuals to specific conditions over others (Hovhannisyan and Vervaeke 2022). The reason is that if sensorimotor individuation constitutes a person's character, then all characters involve a reduction of potential behaviors, limiting the individual's developmental field and predisposing them to specific rigidities and maladaptations. These rigidities endow the person with differential vulnerabilities, which draw idiosyncratic patterns of onset, relapse, and recovery in a person's history of mental health. All living systems are precarious, and thus, vulnerable. However, given the idiosyncratic nature of developmental individuation processes, not all persons are vulnerable in the same way and to the same extent.

In this regard, non-linear dynamical models offer both the mathematical and conceptual tools necessary to model mental conditions in a processual fashion and to understand developmental rigidities (Nelson et al. 2017; Olthof et al. 2023). Mental disorders are represented as dynamical networks of collective variables (Borsboom 2017), whose evolution over time is explained by general principles of pattern formation in complex adaptive systems. Psychopathological states, such as persistent sadness or fluctuating moods, are interpreted as attractors—stable states that the system naturally gravitates towards. Mental disorders are thus understood as "stuck states". For instance, a person may be drawn into a state of depression, or cycle between depressive and manic episodes, forming what is called a fixed-point or limit-cycle attractor. Certain psychopathological dynamics unfold slowly, such as episodes of depression or psychosis, which can remain stable for extended periods, often lasting for months. In contrast, other dynamics evolve rapidly, like panic attacks, which represent attractors that persist for only a few minutes. And most of them present a combination of attractors at different timescales that influence each other. The persistence of such habitual states over time, especially when an individual cannot escape them and overrule the performance of other situationally relevant habits and behaviors, is a common feature of psychopathology (Ramírez-Vizcaya and Froese 2019).

In mental disorders the brain-body-environment dynamics can be either too flexible (e.g., psychotic and dissociative conditions) or too rigid (e.g., neurotic conditions), but in either cases, they imply a diminishment of metastability and meta-flexibility in the behavior of the system. A healthy system, in order to cope with changes in the environment, must keep a relative degree of metastability, that is, a state of mixture between stable and unstable patterns, not being trapped into rigid attractors, but not being disintegrated either. This requires meta-flexibility —the ability to dynamically adjust its level of flexibility in response to a stressor while maintaining a degree of robustness in the system. This second-order flexibility allows resilient systems to balance change and preservation and to maintain an adequate range of degrees of freedom, while ensuring their integrity under varying conditions. Note that meta-flexibility and metastability define mental disorders in a continuous-dimensional manner, rather than establishing a categorical and binary health-disease demarcation. Yet, the explanatory relevance of dynamical models is that although they describe phenomena at a particular level of analysis, their dynamics can be linked to higher-scale processes. This allows us to describe and explain mental disorders in a processual, multiscale and multidimensional manner.

8.3 Relational Ontology

The relational ontology underpinning the enactive approach posits that cognition is inherently situated within the continuous, dynamic interaction between an individual and its sociomaterial environment. This framework rejects the traditional view of cognition as an isolated, brain-bound process, instead framing it as emergent from embodied engagement with the world. Cognition is thus not a matter of passively representing the world, but an active engagement with it, where the individual exercises autonomy in shaping and being shaped by its sociomaterial environment.

Ontologically, the relational nature of cognitive agents can be understood in two complementary ways (Dengsø and Kirchhoff 2023): On the one hand, the agent and its environment can be viewed as autonomous and individualized systems that interact and form relationships with each other, that is, constitutive processes precede interactive ones, with the relata being a priori separated entities that interact externally. On the other hand, both systems can be understood as differentiated through distributed, metastable relations, where the entities (relata) do not precede the relations but rather co-exist with and are shaped by them. I shall focus on this latter view, where agent and environment are not pre-existing, independent entities placed into relation, but instead, it is the broader relational dynamics that co-constitute and individuate them. Here, autonomy is understood, not as a property of individuals, but as emerging from distributed entangled processes along the individual-environment system that establish significant local asymmetries between them (McGann 2024). This relational perspective is present in the Simondonian turn in enactivism (Di Paolo 2021; García 2023; García and Arandia 2022; James 2020), where individuals are said to emerge from matrices of relational forces, and also in Hans Jonas's concept of "mediation", which refers to the human "inwardness" or self-referentiality as a form of dialectical achievement of encounters with others (Benevides et al. 2023). This shift proposes to look at sympoiesis (co-organization) rather than autopoiesis (self-organization) as fundamental biological structures that support mindedness (Dengsø and Kirchhoff 2023). As McGann puts it, "we become individuals, therefore, not by separation, but by differential entanglement" (2024, p. 8).

The enactive approach to social cognition as participatory sense-making (De Jaegher and Di Paolo 2007), can indeed be read from these two perspectives. Participatory sense-making explains how two autonomous agents come to create shared meanings within an autonomous relational domain that is, to some extent, independent from individual intentions. The autonomy of the relational domain allows for subtle or transformative modulations of individual meaning-making processes, enabling the co-creation of new meanings that would not be accessible to individuals in isolation. In its original formulation, social cognition is viewed as the process by which individual and autonomous agents come together to engage in shared meanings, highlighting the need to maintain individual autonomy for a social interaction to be genuinely social. However, from this latter relational perspective, participatory sense-making may also be seen as the process by which individuals engage with and shape each other's potential for growth and development, that is, the way by which we influence in the individuation of the other. Indeed, taking a diachronic perspective, there is a sense in which the interactants are individuated by the wider relational system they are elements of, via "global to local" or "top down" constitution. Rather than assuming that individuals exist independently before any interaction, we can view interaction itself as the force for individuation (James and Loaiza 2020). Humans are inherently relational beings, assemblies of historically developed interpersonal interactions and affective entanglements that define and individuate their embodied being-in-the-world.

Following this perspective shift, a recent relational turn has taken place calling for a figure/ground inversion between social and non-social cognition (e.g., Dingemanse et al. 2023; Trasmundi and Steffensen 2024). The point is to challenge the prevailing belief in cognitive science that by understanding basic, non-social cognition (e.g., perception of objects, navigation, etc.) we will be better equipped to understand social cognition as its complex derivative. However, this individualistic approach may be misleading, as the human brain has evolved in response to social demands and is largely shaped by our need to monitor and navigate complex social contexts (Dunbar 1998). Human cognitive flexibility arises from neoteny, as much of our cognitive development takes place postnatally through social interactions. This social embedding fosters remarkable plasticity, enabling learning, habit formation, and emotional attachment, which in turn enhance our ability to adapt to diverse socio-ecological niches through enculturation. This is not trivial, as many of the autonomous processes that constitute our sensorimotor identity extend to our coordination with others. Even the most fundamental sensorimotor schemes, like the Piagetian breastfeeding scheme, require coordination between the child and caregiver. Indeed, developmental psychologists have long noted the innate "readiness to interact", coordinate and imitate present in human infants (Meltzoff 2002; Reddy 2008).

The key point here is that human openness to interaction and underdeveloped potential are not only essential for growth but also create the conditions for mental disorders to emerge (Brüne 2000). This cognitive flexibility allows for diverse, socially shaped developmental paths to become maladaptive. Indeed, a widespread symptom in diverse mental disorders involves interpersonal misattunement, a sense of disconnectedness from a shared world and altered forms of interpersonal coordination (Gallagher 2013). Examples in adulthood can be found in personality disorders, where the core issue often lies in the individual's impaired ability to skillfully and adaptively engage with others and conform to socially accepted norms (Roche and Ansell 2020; Wright et al. 2022) or in schizophrenia –which has been traditionally understood as disturbances of the individual self in phenomenological psychopathology, but which also involves altered patterns of self- and other-centeredness perspective taking (Kyselo 2016; Nelson et al. 2009). Moreover, human developmental openness and freedom often manifest as existential anxiety and fear, underlying many disorders (Fuchs 2013). In other words, dysfunction arises when one fails to fulfill an evolutionarily fixed function, whereas disorder stems from maladaptive coping mechanisms arising in social development.

Consequently, mental disorders should not be conceptualized merely as isolated individual conditions but rather as interactively organized processes. Enactivism supports a systemic approach, emphasizing how social values and norms are embodied through interactions, shaping character, habits, and social repertoires. Rather than being strictly individual or social, mental disorders arise as (mal)adaptive responses relative to particular social contexts (e.g., adaptive preferences, Maiese 2026, this volume). This is evident in concepts like the "double empathy problem" in autism (Milton et al. 2018) and relational models of disability. While neural correlates of disorders may exist, they reflect circular causal processes involving social interactions rather than a fixed underlying dysfunction. In other words, there is no singular brain-based cause behind interpersonal difficulties—rather, these difficulties both constitute and express the disorder over time. The issue is not just "in the head" but in our ability to coordinate and engage with others, which are interpersonally developed skills. Mental disorders emerge thus as relational phenomena—impairments in the ability to engage in successful social interactions, meet others' expectations, coordinate behaviors, and maintain standards of predictability in interpersonal relationships.

In conclusion, although individual autonomy and its impairments have often been the focus of describing mental disorders, autonomy should be viewed as a regulatory process that extends diachronically to the history of interactions with the sociomaterial environment. The relational and processual view of cognition presented in this chapter redefines autonomy as a distributed phenomenon, sustained and transformed within the web of interpersonal entanglements and contextual relations in which the subject is embedded. Within this framework, psychiatric conditions cannot be understood merely as internal failures of the individual but as dynamic configurations that emerge from interaction patterns across multiple levels of organization and constitute forms of the individual's relational patterns. Mental disorders are seen as processes evolving along the developmental history of the person and compromise their metaflexibility and metastability in their relational habit repertoire. Mental disorders, therefore, are no longer seen as isolated dysfunctions but as specific modes of regulation and dysregulation within a broader relational system. This shift in perspective not only challenges traditional reductionist approaches but also opens new pathways for understanding and addressing mental health, fostering interventions that consider both the individual's organization and the interpersonal and collective dynamics that sustain it (e.g., promoting salutogenic environments, Menatti 2026, this volume).

Acknowledgements EG acknowledges funding from IAS-Research group funding IT1668-22 (Basque Government); grants PID2019-104576GB-I00 "Outonomy" and PID2023-147251NB-I00 "Outagencies", funded by MCIU/AEI/10.13039/501100011033 and FEDER/UE. This work has also received funding from the European Union's Horizon Europe Marie Skłodowska-Curie postdoctoral grant agreement No. 101205668.

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Chapter 9
Salutogenesis, Adaptivity and the Continuum of Health

Laura Menatti

Abstract Salutogenesis is a theory of health and disease that emphasises the promotion of beneficial measures besides the prevention of risk factors and counteracting pathogens. This paper reframes salutogenesis by situating it within the account of biological autonomy and adaptivity, drawing on recent developments in organisational accounts of living systems. By doing so, the paper provides new insights into the relational, situated and continuous nature of health, and it introduces the importance of supportive 'salutogenic environments' to foster adaptivity as the individual and collective capacity to change ourselves, including our environments, to promote health.

Keywords Adaptivity · Biological autonomy · Salutogenic environments · Health continuum · Organism-environment interaction

9.1 Introduction

The salutogenic approach represents a paradigm shift in how we conceptualise health and well-being. Salutogenesis emphasises the promotion of beneficial measures rather than solely focusing on the prevention of risk factors, in contrast to medical approaches centred on pathogenesis. Furthermore, medicine has been criticised for employing a compartmentalised view that overlooks broader ecological contexts. There is growing recognition that public health and biomedical frameworks need to integrate ecological considerations, as evidenced by approaches like *OneHealth* and *planetary health*, which acknowledge the fundamental connections between human well-being and environmental factors.

This chapter examines the foundations of salutogenesis, relating them to the notion of autonomy in biological systems and its significant contribution to contemporary healthcare practices. The analysis of the *Sense of Coherence* and the concept of

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X. E. Barandiaran and A. Etxeberria (eds.), *Outonomy*,
SpringerBriefs in Philosophy, https://doi.org/10.1007/978-3-032-05501-9_9

health as a *continuum* shows how salutogenesis can provide a more comprehensive perspective on human health. Importantly, the paper introduces the novel concept of 'salutogenic environments', which, when examined through the lens of autonomy and adaptation, reveals how health is related to how organisms actively engage with and adapt to their surroundings rather than merely reacting to environmental pressures. This perspective offers a significant advancement in our understanding of the dynamic relationship between health, autonomy, and environmental interactions.

9.2 What Is Salutogenesis? A Short History and Its Pillars

The term salutogenesis is derived from the Latin words *salus* (health) and *genesis* (production, generation), signifying 'carrier of health'. Salutogenesis is a theory of health and disease that emphasises the promotion of beneficial measures besides the prevention of risk factors and counteracting pathogens.

A defining characteristic of salutogenesis is its proactive approach to health that focuses on enhancing factors that can improve individuals' health and their adaptive capacities with respect to the social and natural environment. To illustrate the foundational concept of salutogenesis compared to pathogenesis, scholars have employed the metaphor of the 'river of life' (Antonovsky 1979; Eriksson and Lindström 2008). According to this metaphor, solely promoting health by avoiding stressors or building bridges across the river to save people from drowning remains within a pathogenic approach. Instead, medicine should empower individuals to navigate these waters independently through health promotion, education, and preventive strategies that foster well-being without paternalism.

The salutogenic framework was developed by Aaron Antonovsky (1979, 1987), a medical sociologist whose research primarily examined stress, particularly the interplay between physiological and social stressors and their impact on health and disease across various social groups. These groups, based mainly in the United States and Israel, included menopausal women, Holocaust survivors, minorities, marginal populations, as well as diverse patient categories. Antonovsky dedicated his efforts to implementing and applying the salutogenic framework until his passing in 1994.

Antonovsky was a sociologist of health, yet his work was influenced by endocrinology, microbiology, psychiatry, and psychology to create a conceptualisation of the complexity of health, disease, and illness (Vinje et al. 2016). His model has gained importance in medicine and the social sciences, with applications across various fields (Mittelmark and Bauer 2017; Mittelmark and Bauer 2022). It is also utilised in decision-making processes, patient-centred medicine, and integrative care practices (Grover et al. 2022; Gartner et al. 2022; Menatti et al. 2022). Salutogenesis provides a specific framework and tools, such as the Sense of Coherence scale, to assess patient needs and manage stressors (Grover et al. 2022; Gartner et al. 2022; Menatti et al. 2022; Pelikan 2022; see also Dietscher et al. 2022).

In this chapter, I explore the salutogenic approach to health, its relationship with the environment and its connection to the notion of autonomy. Two main elements will be discussed: the concept of a *continuum* of health and the relationship between the organism and its environment, particularly the capacity to adapt and change.

A first pillar of the salutogenic approach developed by Antonovsky is *The Sense of Coherence*. It describes individual and collective capabilities to adapt to diverse life stressors. It reflects how individuals perceive and respond to their social surrounding, encompassing three key aspects: understanding (comprehensibility), resourcefulness (manageability), and purpose (meaningfulness). Understanding represents the capacity to make sense of and comprehend what is occurring around oneself, grasping the nature of challenges faced. Resourcefulness is the belief that one has access to sufficient resources, both personal and social, to address and manage situations that arise. Purpose involves the ability to find meaning and motivation within circumstances (Antonovsky 1996, 15). These aspects are measured through the Sense of Coherence Scale (see Eriksson and Contu 2022) to assess the collective and individual coping mechanisms that enable people to adjust to various situations and develop the necessary resources to handle changes and challenges. This idea closely aligns with biological autonomy, particularly with self-regulation and self-maintenance. They both address how organisms (or individuals) perceive, manage, and find meaning in their environment, offering a wider perspective on adaptation and well-being. Section 9.4 will analyse this adaptive capacity as an improved conceptualisation of health.

The other pillar of the salutogenic approach is the idea of health as a *continuum*. This idea, further discussed in Sect. 9.3, helps update current conceptualisations of health. Salutogenesis posits that health exists on a continuum between the two poles of complete wellness and illness. It encourages healthcare professionals to consider not only the treatment of diseases but also the strengthening of patients' resources and coping abilities. It fosters a more balanced, comprehensive understanding of human health and resilience.

In summary, salutogenesis advocates for a more systemic understanding of health that incorporates both preventive measures and proactive strategies while complementing pathogenic approaches with salutogenic initiatives (Becker et al. 2010).

9.3 Differences Between Salutogenesis, Health Promotion and Preventive Health

I argue that while providing innovative concepts on health, salutogenesis differs from traditional medical frameworks by focusing on adaptation and autonomy, extending beyond conventional preventive medicine and health promotion.

Preventive medicine typically refers to efforts aimed at disease prevention, both at the individual and community levels. It encompasses activities that reduce the risk of disease, disability, and death (Britannica 2022; see also Nikku and Eriksson 2012). Historical practices in preventive medicine included dietary prescriptions and the isolation of sick individuals (Becker 1988), as well as interventions in living and healthcare environments (Ward Thompson 2011). Measures such as quarantines and environmental management to avoid disease have been documented (Meloni 2021; Martini and Lippi 2021). Yet, contemporary medicine has focused on pathogenic risks following the development of germ theory and the discoveries of L. Pasteur and R. Koch (Snowden 2020; Bingham et al. 2004; Gaynes 2019; Gradmann 2009; Porte 1998).

Health promotion (for a history see Bingenheimer et al. 2003; Raingruber 2012; Tulchinsky and Varavikova 2015), instead, has been defined as the process of 'enabling people to increase control over their health determinants in order to improve their health and thereby be able to live an active and productive life', as stated in the Ottawa Charter (WHO 1986). In 2009, the *American Journal of Health Promotion* provided a comprehensive definition of health promotion aimed at the achievement of the *optimal state of health.* It conceived health promotion as the art and science of helping individuals align their passions with *optimal* health, enhancing motivation for lifestyle changes that achieve a balanced state of physical, emotional, social, spiritual, and intellectual well-being (O'Donnell 2009, iv).

The salutogenic approach acknowledges both prevention and health promotion at the individual and community levels. Antonovsky's commentators note that salutogenesis aligns with the Ottawa Charter, in recognising social determinants, setting objectives for an active life, and promoting dynamic processes toward health (Lindröm and Eriksson 2005). However, salutogenesis adds significant theoretical dimensions to health promotion by shifting focus from individual risks to population health and communities not necessarily at risk, advocating for a broader understanding of health that encompasses all aspects of life (Antonovsky 1996). While preventive medicine concentrates on pathogenic aspects and risk factors, salutogenesis avoids idealised notions of 'optimal health', addressing concerns in line with the critics of the WHO's 1948 definition being overly idealised (Saracci 1997; Bircher 2005). Rather than merely maintaining wellness, salutogenesis focuses on understanding the complexities of human health systems (Antonovsky 1996).

Salutogenesis emphasises health as a *continuum* rather than an ideal state opposed to illness. Individual life encompasses variation across different states between pure health and death. Compared to preventive medicine and health promotion, salutogenesis adopts a proactive stance by focusing on creating supportive social contexts and highlighting *adaptive capacities* within health dynamics (Becker et al. 2010; Antonovsky 1996).

Having established these distinctions, we can examine how the salutogenic approach contributes to our understanding of health through the health continuum and adaptivity. These concepts are particularly relevant when seen through the lens of biological autonomy, to emphasise how organisms actively engage with their environment rather than merely respond to external pressures.

9.4 Health as a *Continuum* and Health as Adaptivity

Salutogenesis, as I reframe it by including environmental interactions, offers valuable insights for updating our theoretical and practical understanding of health and well-being. The first general lesson derived from it is the need for a proactive stance that prioritises enabling factors and environments supporting people's adaptive capabilities. This perspective shifts our attention beyond treating illness and identifying pathogenic risks to actively promoting health and well-being, by building frameworks, strategies and actions to improve and empower people's capabilities (see Becker et al. 2010).

Two key notions from the salutogenic account may help update our idea of health: *continuum* and *adaptivity*. Both concepts are already in *nuce* in the salutogenic account, and can be further developed through the philosophy of medicine and of biology. Antonovsky's cognisance of the coeval debates on adaptation and homeostasis in biological systems (Vinje et al. 2016) facilitates the integration of his analysis into contemporary philosophical discourses on health, biology, and medicine.

The *continuum* of health concept, introduced by Antonovsky (1979), challenges the rigid healthy/sick dichotomy by introducing an 'ease/dis-ease continuum'. This model views health as a multifaceted, dynamic process where individuals constantly navigate between states of health and illness throughout their lives. Physical and social stressors influence an individual's position on this continuum, pushing them toward either pathogenic or salutogenic ends. Health is characterised by this continuous movement between intertwined pathogenic and salutogenic states. This perspective aligns with positive definitions of health, including the WHO's 1948 view, and it is especially relevant to chronic conditions. On this view, the emergence of a disease does not necessarily equate to a complete loss of health but rather represents a shift along the continuum (for a different characterisation of life as a trajectory rather than a continuum, see Etxeberria 2020).

Building on the continuum model, Rose (1992) introduced the 'continuum of risks and severity' concept, advocating for population-wide health strategies rather than focusing solely on high-risk individuals. Similarly, Valles (2018) proposed viewing health as a lifelong phenomenon, emphasising the dynamic interaction between individual and population health within social contexts. These perspectives highlight the importance of considering health as a continuous, complex process influenced by various factors over time, rather than a series of discrete states.

Strictly related to the idea of continuum is the concept of adaptation. Antonovsky discusses adaptation in several essays, framing health as a problem of disequilibrium concerning the "active adaptation to an environment in which stressors are omnipresent and inevitable" (Vinje et al. 2017). He argues that salutogenesis paves the way for rehabilitating stressors in human life through a continuous process of adaptation. In this context, Antonovsky highlights the potential of variability and disequilibrium for health by adopting the term "negative entropy" or "negentropy"

(Antonovsky 1987, pp. 8–9), which underscores that salutogenesis focuses on stressors that are inevitably present in the environment. These terms refer to the process of creating structure in the face of life's inherent chaos, emphasising the human capacity to generate health and meaning despite omnipresent stressors.

In philosophy of biology, the notion of adaptation employed by Antonovsky is related to adaptivity. Adaptivity has been recently developed in the organisational account of regulatory control (Bich et al. 2016). Di Paolo (2005) defines adaptivity as the ability of a system, like an organism, to sustain its viability in its environment through self-regulation. It refers to how well a system can manage changes in its surroundings. This concept has been developed into a theoretical framework in philosophy of biology about controlling the constraints responsible for a system's internal processes and behaviours (Bich and Bechtel 2026, this volume). This control involves adjusting constraints and realising new physiological and behavioural regimes based on changes in both internal and external conditions. Special constraints or mechanisms carry out this adjustment by assessing disturbances and responding appropriately.

Starting from these conceptual developments, recent work in the philosophy of biology and philosophy of medicine can help reframe health as a movement along a continuum defined by the adaptive capacities of human beings to the everyday environmental stressors encountered in their environments.

9.5 The Salutogenic Approach and the Environments for Health

To complement the salutogenic approach, I propose in this final section an additional key concept: the interconnection between health, adaptive capabilities, and the environments or what I could define as 'salutogenic environments'. By considering the environmental aspect, we recognise that health is not just about internal processes, but also about how well an individual can adapt to and interact with her surroundings. Understanding this relationship can provide a more comprehensive view of health, acknowledging the dynamic interplay between an organism's well-being, its ability to adapt, and the environmental context in which it exists.

As related to health, the external environment is often complex. It encompasses non-genetic influences, including physical, social, and cultural factors. It can be categorised as natural, altered, or built, each presenting unique health risks. This classification aids in analysing environmental diseases and developing targeted public health policies to address both human and ecosystem risks (Riegelman and Kirkwood 2019).

Yet the environment in medicine is still often considered as pathogenic; it is depicted as a source of hazards that need to be blocked, counteracted, or eliminated. The pathogenic view of the environment tends to overlook the positive or preventive interactions aimed at fostering, rather than just re-establishing health (Menatti et al. 2022; see also Garcia 2025, this volume). Environmental psychology, cognitive science and architecture have been investigating the positive role of the environment for health and well-being. Mostly natural spaces are considered to promote stress reduction and restore attention in diverse contexts (Ulrich 1984; Menatti and Casado da Rocha 2016; see also *Evidence Based Design*). In medicine, this poses various concerns for evidence-based studies, even though medical sciences are increasingly recognising the role of the environment in prevention, care and also for the well-being of healthcare professionals (Ulrich et al. 2020; Whall et al. 1997).

An important theoretical and philosophical step in this direction should imply the introduction and analysis of the idea of *salutogenic environments*, which are aspects of our surroundings that can positively impact health and well-being. These environments encompass physical, social, and cultural elements that promote health by fostering adaptivity for individuals, groups, or entire populations, for their different capabilities and needs.

On this view, environments are considered salutogenic when they promote health by emphasising active adaptation and engagement with the surroundings. The basic idea is to consider individuals and groups not simply as subjected to the effect of the environment and trying to counteract it, but as capable of adaptivity, that is, of modifying themselves and the environment to promote their viability. Accordingly, this approach views the environment's impact on health as relational, dependent on people's adaptive capabilities. It supports individuals along the health continuum, seeing environmental variability as an opportunity for growth and viable change rather than just a risk. Salutogenic environments, therefore, are those spaces that facilitate a dynamic, health-enhancing relationship between people and their surroundings. Taking these points into consideration can be particularly valuable for designing and managing both public and private spaces, starting from, but not limited to, healthcare facilities.

Acknowledgements LM acknowledges funding from grants PID2019-104576GB-I00 "Outonomy" and PID2023-147251NB-I00 "Outagencies", funded by MCIU/AEI/10.13039/501100011033 https://doi.org/10.13039/501100011033 and FEDER/UE.

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Chapter 10
Pain Beyond Nociception: A Biological Autonomy Perspective

Alberto Monterde-Fuertes

Abstract Pain science and management have long grappled with significant conceptual challenges, particularly the differentiation of pain from nociception. This chapter addresses this challenge by adopting the framework of biological autonomy, which conceptualizes living systems as self-regulating entities dynamically interacting with their environments. From this perspective, pain emerges as a context-sensitive phenomenon that protects autonomy by guiding adaptive behavior and anticipating future threats. In contrast, nociception is a mechanistic process that transduces and transmits noxious stimuli to elicit protective reflexes. By integrating insights from pain research, medicine, and philosophy, the chapter advances a relational and functional understanding of pain while outlining its practical implications.

Keywords Pain · Nociception · Biological autonomy · Biopsychosocial model · Reductionism · Adaptive behaviors · Organism-environment interaction

10.1 Introduction

The study of pain has posed conceptual and empirical challenges in scientific research and medicine. The Cartesian approach, dominant in the twentieth-century, conceptualized pain as a mechanical response to tissue damage. Pain was thus viewed as a physiological process directly linked to noxious stimuli, conflating it with nociception—defined as the neural encoding of harmful stimuli (Melzack and Wall 1996). However, reductionist accounts failed to capture pain's complexity and subjectivity. These limitations prompted a paradigm shift, recognizing pain as a multidimensional, emergent phenomenon shaped by psychological, social, and environmental factors (Casey and Melzack 1968; Melzack and Wall 1996).The biopsychosocial model further expanded this view, integrating cognitive, emotional, and sociocultural dimensions (Adams and Turk 2018).

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X. E. Barandiaran and A. Etxeberria (eds.), *Outonomy*,
SpringerBriefs in Philosophy, https://doi.org/10.1007/978-3-032-05501-9_10

Despite these advances, challenges remain in conceptualizing pain and nociception as distinct phenomena (Butler and Moseley 2017; Lee et al. 2020). This chapter addresses these challenges through the biological autonomy framework, emphasizing pain's relational and functional roles in preserving autonomy. By situating both pain and nociception within this framework, I argue for a more substatian distinction between their respective organizational functions. Pain is a subjective and integrative phenomenon mediating an organism's interaction with its environment. At the same time, nociception is a mechanistic process confined to detecting and transmitting noxious stimuli to elicit withdrawal responses. This distinction has practical implications, underscoring the need for interdisciplinary, patient-centered approaches to pain management that integrate biological, psychological, and social dimensions.

This chapter proceeds in four sections. First, I examine the conceptual challenges in distinguishing pain from nociception. Next, I introduce the biological autonomy framework, highlighting its potential to clarify the distinct roles of pain and nociception. In the third section, I apply this framework to demonstrate how pain emerges as a relational, adaptive phenomenon that integrates sensory, emotional, and contextual dimensions to promote self-maintenance. Finally, I explore the practical implications of this approach, advocating for evidence-based interdisciplinary strategies in pain research and management.

10.2 The Challenge of Distinguishing Pain from Nociception

Distinguishing pain from nociception has been a longstanding challenge in pain science (Lee et al. 2020; Melzack and Wall 1996). Nociception is the neural encoding of potentially harmful stimuli (Woolf and Ma 2007), while pain is a subjective, integrative experience shaped by internal and external contexts (Butler and Moseley 2017; Melzack and Wall 1996). This distinction has often been oversimplified, reducing pain explanations to nociceptive mechanisms (e.g., Sweet 1959). However, this reductionist stance overlooks pain's complexity and variability, which extends far beyond nociceptive input (Butler and Moseley 2017; Melzack and Wall 1996). It also conflates two different questions: explaining what causes a painful event versus what causes pain to be subjective. Although knowledge of the mechanisms that cause a painful event has increased over time, it cannot account for what causes pain to be subjective (Melzack 1996). Addressing that requires evidence on how pain perception is modulated beyond purely physiological mechanisms (Adams and Turk 2018).

Pain scientists have long argued that pain and nociception are distinct yet related phenomena. Earlier accounts justified this distinction by emphasizing pain's complexity, which resisted its identification with nociceptive mechanisms (Casey and Melzack 1968; Melzack and Wall 1996). However, these arguments lacked conceptual precision, relying on hypothesized mechanisms. Contemporary perspectives describe pain as a complex emergent phenomenon, related to nociception but not limited to it. Most accounts now hold that pain arises when an organism perceives a threat and cannot be deduced from physiology alone (Butler and Moseley 2017; Gifford 2014). Yet this view, often grounded in the biopsychosocial (BPS) model, has its own limits. The model is frequently criticized for failing to clearly define the relationships among biological, psychological, and social factors, raising concerns about its clinical and conceptual utility (Quintner et al. 2007).

Addressing these conceptual and practical challenges requires examining the distinct biological roles of pain and nociception. Historically, pain's function has been framed through two perspectives: exteroception and interoception. Exteroception refers to the sensory detection of stimuli originating from outside the body, such as touch, temperature, and potential injury. In this view, pain functions as an alarm system, responding to nociceptive signals to protect the organism from harm (Sherrington 1906). Interoception, by contrast, involves sensing internal body states, such as hunger, thirst, or visceral discomfort. From this perspective, pain guides an organism's behaviour to avoid further harm or promote (Craig 2003). While often seen as mutually exclusive, these views can be complementary (Price 2017), with pain informing the organism about both external threats and internal states vital to survival.

Yet, this combined view relies on the assumption that pain's main role is to convey information about damage. Laurenz Casser (2021) challenges this assumption, arguing that empirical findings undermine pain's role as an informational signal. For example, modulation mechanisms within the nervous system can inhibit or amplify pain perception independent of tissue damage, revealing a dissociation between pain and nociceptive input. Casser also notes little evidence that pain was evolutionarily selected to inform organisms about harm. These points question the informational model and highlight the need for a clearer functional distinction between and nociception.

These challenges call for a framework that accommodates both the relational and functional aspects of pain and nociception. Biological autonomy is well-positioned to fulfill this role, offering a conceptual basis for biological functions and organism-environment interactions. Situating pain and nociception within the biological autonomy framework elucidates their distinct organizational roles and resolves these conceptual challenges.

10.3 Biological Autonomy: A Theoretical Framework for Understanding Pain

The biological autonomy framework offers a compelling lens for understanding the differentiation of pain from nociception. Biological autonomy conceptualizes living systems as capable of producing components to maintain themselves despite external changes, ensuring survival and reproduction (Moreno and Mossio 2015). This capability is grounded in organizational closure, a self-maintaining network of processes where components sustain one another and regulate their activities (Bich 2024). Closure enables a system to maintain its organization and functional integrity while providing a basis for understanding its relative autonomy from the environment.

A key concept within the biological autonomy framework is the notion of organizational functions (Mossio et al. 2009). Functions are understood as the contributions of a system's components to maintaining and reproducing the system's organization. This account emphasizes that biological functions are inherently tied to the system's capacity for self-maintenance. By contributing to the system's ongoing integrity, functions acquire normative and teleological significance: they are "good" for the system insofar as they preserve its autonomy. This idea offers a robust theoretical basis for distinguishing the roles of pain and nociception within a self-maintaining organism.

It is important to note that biological autonomy extends beyond internal regulatory mechanisms to encompass an organism's dynamic interactions with its environment. Thus, conceptualizing how organisms actively engage with and modify themselves to adapt to their surroundings, maintain organization, and ensure survival (Bechtel and Bich 2024; Menatti et al. 2022; Saborido and Heras-Escribano 2023). This perspective emphasizes the reciprocal relationships between organisms and their environments: by interacting with and shaping their environments, organisms sustain the conditions necessary for preserving their structural and functional integrity (Menatti 2026, this volume).

Several scholars have recently applied the biological autonomy framework to pain, emphasizing pain's interactive and relational aspects when differentiating it from physiological processes. For instance, John Quintner, Milton Cohen, and collaborators have argued that pain is a subjective experience irreducible to biological substrates while accepting the principles of biological autonomy. For them, pain plays a crucial role in the survival of living beings, which they understand as "integral, autonomous systems" (Cohen et al. 2018, p. 5). If this is true, they contend, "pain is a threat to the autonomy and thus to the existential integrity of a living system" (Cohen et al. 2018, p. 5). Consequently, they defined pain as "a mutually recognizable somatic experience that reflects a person's apprehension of threat to their bodily or existential integrity" (Cohen et al. 2018, p. 6).

According to this view, the self-referential nature of living systems (engaged in continuous interaction with their environments) means that pain emerges in ways that resist reduction to biological, psychological, or social factors alone (Quintner et al. 2007). Their theoretical proposal, influenced by the work of Maturana and Varela (e.g., 1980) conception of autonomy as autopoiesis, highlights the brain's self-referential role within an autopoietic system. This role serves as a foundation for rethinking clinical practice. In this view, the clinical encounter is a meeting of two autopoietic systems, each with its own norms, beliefs, actions, and interpretations of the shared experience called pain (Quintner et al. 2007). When interpreted through the lens of interactive biological autonomy, the clinical encounter becomes a "third space": a moral and epistemic space that requires mutual understanding necessary to foster effective treatment and prevent the stigmatization of suffering. Quintner et al. approach aligns with the enactive concept of participatory sense-making (De Jaegher and Di Paolo 2007), which emphasizes how meaning emerges through social interaction. This enriches the concept of the third space as a site of transformative relational engagement.

Moreover, Keith Farnsworth and Robert Elwood (2023) have explored the evolutionary basis of pain through the lens of biological autonomy. They argue that pain is essential for organisms capable of anticipatory behavioral autonomy (ABA), as it enables context-sensitive action selection grounded in internal predictive models. These models allow organisms to evaluate potential outcomes and flexibly prioritize their responses. On this view, pain is not merely a reflexive reaction to harmful stimuli but a motivational force that drives threat avoidance while supporting the pursuit of higher-order goals. This account aligns with the concept of organizational functions in biological autonomy (Mossio et al. 2009; Saborido and Heras-Escribano 2023), highlighting pain's contribution to self-maintenance by guiding adaptive interactions with the environment. By integrating internal predictive models and responses to external stimuli, organisms can anticipate and evaluate the consequences of their actions (Farnsworth and Elwood 2023), reinforcing the dynamic interplay between internal regulation and environmental engagement (Bechtel and Bich 2024; Menatti et al. 2022). In this light, pain facilitates survival-oriented decision-making within a self-organizing system, extending the phenomena beyond a mechanistic withdrawal response and reflecting both the heterarchical control model (Bich and Bechtel 2026, this volume) and the purposive agency central to autonomy theory (Virenque 2026, this volume).

10.4 Distinguishing Pain from Nociception: A Biological Autonomy Approach

The biological autonomy framework provides a foundation for differentiating pain and nociception, addressing conceptual challenges in scientific discussions on pain. Within this framework, pain is understood as an interactive phenomenon that enables adaptive responses to environmental disturbances (Farnsworth and Elwood 2023). It integrates past experiences, contextual cues, and cultural norms, helping organisms navigate their environments, safeguard survival, and promote self-maintenance (Butler and Moseley 2017; Craig 2003). This dynamic coupling of the organism with its environment underscores pain's organizational role in supporting immediate survival and long-term adaptive capacity.

Therefore, pain, as an emergent phenomenon, operates at a broader organizational level than nociception. While nociception is a mechanistic process confined to detecting and transmitting noxious stimuli to elicit protective reflexes (Baliki and Apkarian 2015; Woolf and Ma 2007), pain encompasses a broader range of sensory, emotional, and contextual dimensions. It guides adaptive behaviors by shaping responses to perceived environmental threats, fostering adequate response (Farnsworth and Elwood 2023; Price 2017). In humans, social, psychological, and cultural influences shape the interactional nature of pain. For example, cultural norms significantly affect how pain is perceived and expressed, shaping coping strategies and treatment outcomes (Orhan et al. 2018). Social contexts also modulate pain experiences, as research shows that social rejection activates brain regions associated with physical pain, such as the anterior cingulate cortex (Eisenberger 2012). Conversely, social bonding can reduce pain perception through the release of endogenous opioids, emphasizing the role of supportive relationships in mitigating pain (Inagaki et al. 2016).

Moreover, clinicians and societal attitudes shape pain narratives, profoundly influencing patients' beliefs and behaviors. For instance, advice such as "lift with your knees, not your back," may lead to overprotection of injured areas, delaying recovery and reinforcing maladaptive beliefs about pain (Darlow et al. 2013). Similarly, patients' expectations regarding recovery or damage can shape their pain perception, with those anticipating severe pain more likely to experience prolonged episodes (Carrière et al. 2023). These examples illustrate how pain emerges as a relational phenomenon, modulated by immediate and broader environmental contexts alongside individual expectations and experiences.

From the perspective of biological autonomy, pain and nociception serve distinct organizational functions. Pain involves organism-environment interactions that guide behaviors to protect autonomy and promote recovery (Butler and Moseley 2017; Craig 2003; Farnsworth and Elwood 2023). Nociception, by contrast, is a mechanistic process that transduces and transmits noxious stimuli to trigger immediate protective reflexes. This distinction clarifies their defining roles: pain engages the whole organism in its ongoing relationship with the environment, whereas nociception operates within neural circuits to support rapid, localized responses (Baliki and Apkarian 2015; Woolf and Ma 2007). By adopting this framework, pain and nociception emerge as complementary yet distinct phenomena, separated by their organizational functions. Pain restrains the organism from harm and promotes healing by modulating behaviour, while nociception triggers withdrawal responses to harmful stimuli. These differentiated roles highlight their unique but complementary contribution to maintaining the organism's autonomy.

10.5 Practical Implications for Pain Research and Pain Management

Clinically, biological autonomy reinforces the need to integrate biological, psychological, and social dimensions in pain management. Because meaning and trust are central to patient-clinician relationships (De Jaegher and Di Paolo 2007; Quintner et al. 2007), empathetic care that empowers patients becomes essential. Addressing psychosocial factors, such as beliefs, fear-avoidance behaviors, and language that foster resilience, is crucial in this process, as these factors shape decision-making, pain perception, and recovery (Butler and Moseley 2017; Gifford 2014). Incorporating patient narratives strengthens trust, validates individual experiences, and ensures care is tailored to the patient's context; aligning with evidence-based biopsychosocial approaches (Gatchel et al. 2014; Staudt 2022).

Key policy recommendations include updating medical curricula to reflect the biopsychosocial complexity of pain, promoting education in evidence-based practice, expanding access to multidisciplinary pain management services in underserved areas, and fostering research on pain's relational and emergent dimensions. The demonstrated effectiveness of interdisciplinary approaches supports these reforms and highlights the urgent need for accessible, patient-centered care to replace outdated treatment practices (Gatchel et al. 2014; Meghani et al. 2012). Embedding these principles bridges conceptual and practical gaps, promoting equitable, evidence-based care that reflects pain's multidimensional reality.

10.6 Conclusion

This chapter has argued that the biological autonomy framework offers a robust foundation for distinguishing pain from nociception (Cohen et al. 2018; Farnsworth and Elwood 2023; Quintner et al. 2007). From this perspective, pain serves an adaptive function by mediating organism–environment interactions and guiding behaviors that promote recovery and protect both existential and physical integrity (Cohen et al. 2018; Farnsworth and Elwood 2023; Price 2017). In contrast, nociception functions as a mechanistic process, limited to detecting and transmitting noxious stimuli to elicit withdrawal protective responses (Baliki and Apkarian 2015; Woolf and Ma 2007). This perspective not only situates pain within the systemic dynamics of biological autonomy but also highlights its extended dimensions, including the relational interplay with environmental factors (Bechtel and Bich 2024; Menatti et al. 2022) and social contexts (De Jaegher and Di Paolo 2007), which jointly contribute to the organism's capacity for self-maintenance.

This distinction highlights the need to move beyond reductionist and overly simplistic pain models that conflate pain with nociception (Quintner et al. 2007). The biological autonomy framework emphasizes pain's relational and organizational roles, accounting for the cultural, social, and psychological factors that modulate pain (Eisenberger 2012; Orhan et al. 2018). It thus provides a comprehensive conceptual basis that bridges scientific, philosophical, and clinical perspectives on pain. In doing so, it reinforces and deepens theoretical models such as the biopsychosocial approach (Adams and Turk 2018) and understanding of pain as an emergent phenomenon (Butler and Moseley 2017).

Viewing pain through the lens of biological autonomy reinforces the need for interdisciplinary, patient-centered approaches that integrate biological, psychological, and social dimensions. This perspective fosters resilience and autonomy through participatory sense-making and culturally sensitive care (Butler and Moseley 2017;

De Jaegher and Di Paolo 2007; Gifford 2014). It also advocates incorporating patient narratives into clinical practice, attending to the relational dynamics of therapeutic encounters, and promoting interventions tailored to individual and contextual factors (Butler and Moseley 2017; Gifford 2014). At a systemic level, supports reforms in medical education to reflect pain's complexity, the expansion of access to multidisciplinary care (Gatchel et al. 2014; Meghani et al. 2012), and ongoing research into pain's emergent and relational dimensions. By adopting these principles, the biological autonomy framework bridges conceptual and clinical gaps, advancing pain science and medical practice. Ultimately, it offers a pathway toward equitable, evidence-based care that respects the multidimensional reality of pain, promoting recovery, autonomy, and well-being for individuals and communities alike.

Acknowledgements I thank the editors for their diligent work and helpful comments. I'm also grateful to my supervisors, Leonardo Bich and Cristian Saborido, for their guidance on various drafts. A.M.F acknowledges funding from IAS-Research group funding IT1668-22 (Basque Government); grants PID2019-104576GB-I00 "Outonomy" and PID2023-147251NB-I00 "Outagencies", funded by MCIU/AEI/10.13039/501100011033 and FEDER/UE. This work was also supported by grant PID2021-128835NB-I00 "NORMABioMed" and the Basque Government predoctoral grant PRE_2022_2_0148.

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Part IV

Technology, Ecology & Politics

Chapter 11
Autonomy and Technology: From Instrumentalism to Technocomplexity

Antonio Calleja-López, Marta Pérez-Verdugo, and Xabier E. Barandiaran

Abstract In this chapter, we briefly present different visions of the relationships between technology and autonomy. We accomplish this by a historical and (partly) dialectical exploration of three positions. We start with the modern thesis by which autonomous humans instrumentalize tools and techniques for their own benefit and self-determination. Next, we address the antithesis: the notion that technological systems have become autonomous, subordinating people to their own self-maintenance. Finally, we explore a synthetic position, which underlines that the only space for autonomy in a technologically mediated world is a technopolitical autonomy that takes the individual beyond itself, back to the ontotechnical constitution of its being, and forward into a personal and collective, ethical and political, participation in its becoming.

Keywords Instrumentalism · Autonomy of Technology · Technopolitical Autonomy · Technocomplexity

11.1 Thesis. Technoinstrumentalism: Politics and Morality Subordinate Technique

Although the condition, practice and experience of autonomy may be traced back to early human societies, its western conceptualization derives from the ancient greek notion of αὐτονομία, composed of "*autos*" (self) and "*nomos*" (norm, rule). Etymologically, its meaning points to the capacity of creating, having or living by

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X. E. Barandiaran and A. Etxeberria (eds.), *Outonomy*,
SpringerBriefs in Philosophy, https://doi.org/10.1007/978-3-032-05501-9_11

"one's own norm or law". Contrary to much contemporary understanding, in its original sense autonomy had a predominantly collective and political character because the self (*autos*) it primarily referred to was the city (*polis)*, which valued its self-determination against external powers. Meanwhile, technique (*tekne)* was a form of know-how, art, craft, or skill, perceived as a questionable complement to nature (*physis)* (Mitcham 1994, Epilogue). According to the Platonic version of the myth of Prometheus, fire and techniques were given to humanity to complement a human body lacking key survival capacities. But techniques had to be complemented, in turn, with justice (*dike*) and other virtues to ensure collective flourishing. More broadly, in Ancient Greece, techniques and technical work were symbolically and materially subordinated to philosophical and political life.

The concept of autonomy revived in the sixteenth century still with a political meaning. But during the seventeenth, the concept of sovereignty came to occupy its place on the political field, and autonomy shifted towards a moral and personal understanding, associated with debates concerning freedom of conscience (Rosich 2020). This process culminated in the eighteenth century in the work of Immanuel Kant. For Kant, human freedom and morality are grounded in the subject's ability to discover a categorical imperative and align its will with it, not as a vassal adhering to an extrinsic rule (heteronomy), but as a rational, universal legislator capable of identifying, sanctioning, and following an endogenous, universal norm (Kant 1998).

These transformations correlated with social, cultural and technical changes. The late medieval and early modern rise in relevance of mechanical arts had convinced Francis Bacon that science and arts were key instruments for salvation, commanded by God to be deployed to control nature, rather than to complement it occasionally as suggested by the ancient greeks. The scientific revolution (associated to a centuries long accumulation of new artifacts such as mechanic clocks, the printing press, microscopes, or telescopes) saw the world itself as a machine regulated by universal laws, a clockwork built by a clockmaker God that could be measured and controlled by a science that correctly read, and increasingly tinkered with, the mathematical book of nature.

This vision culminated in the Enlightenment and utilitarianism, and bequeathed a position that is part of our common sense nowadays: technological instrumentalism (or technoinstrumentalism). From this perspective, techniques and artifacts (progressively tied to science, which would ultimately bring about modern technology[1]) are instruments, axiologically neutral and controlled means to achieve predefined ends. In the early days of the industrial revolution, the modern narrative went beyond Bacon and suggested that the "God hypothesis" was no more necessary (as stated by Laplace), humanity had reached its majority of age (according to Kant), and humans were tool-making animals (as claimed by Benjamin Franklin) ready to save themselves. Humans were becoming autonomous moral subjects able to control and transform a mechanic, axiologically neutral world by means of increasingly powerful and axiologically neutral knowledge, artifacts, and techniques.

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[1] Etimologically, the term "technology" emerged from a combination of *tekne* and *logos,* understood as systematic discourse or rationality.

Etymology is revealing: *instrumentum* comes from *in*, “inside”, *struere*, “to gather together”, and *mentum*, a “means” for something. What grants instruments their ontological status is human intentionality in designing and producing them (Baker 2004). The designer is thereby central. But the focus of modern instrumentalism is even more on the side of the user and its relation to technology. Technological instrumentalism enshrines de vision of “the master” and “the tool”: a powerful and amoral human holding a basic type of artifact (Winner 1978). An *instrumentum* is then understood as a means that can be set inside a course of action to contribute to control and ensure the achievement of its ends (i.e.: the transformation of goals into results) without altering its orientation. That orientation depends primarily on factors such as foresight, interpretation, and evaluation. So, instruments are supposed to affect the subject’s capacity to perceive and act (usually, to increase it) but not warp its thought, its will or its identity. Humans must become more autonomous thanks to technology. As a corollary, when morality (and politics) are considered, good and evil, power and responsibility, lie exclusively with the autonomous subject, its decisions and uses. These are some of the key tenets of technological instrumentalism, a “common sense view” in contemporary societies.

11.2 Antithesis. Technoautonomism: Technology Subordinates Morality and Politics

An antithetic conception of technology, technological autonomism (or technoautonomism) emerged at the end of the 18th century, rose during the 19th, and peaked between the 50s and 70s of the 20th. It can be traced from the foundational myth of Frankenstein (a modern and careless Prometheus) to Chaplin’s Modern Days or the unstoppable war systems of Dr. Strangelove. A milestone within this trajectory is the work of Karl Marx, who, at the peak of the industrial revolution, reconceived the relations between technology and autonomy, be it moral or political. Marx considered techniques and artifacts as forces of production (along factors such as human labour or raw materials) that operate as key drivers in the production and reproduction of society. In correspondence with those forces emerge specific relations of production, such as property relations, which constitute the “economic base” of society. In turn, a social superstructure, including the political and the moral realms, is constituted and acts back upon such a foundation. “The hand-mill gives you a society with the feudal lord; the steam-mill a society with the industrial capitalist” (Marx 1976, p. 166), he sentenced. For Marx, political and moral autonomy are socioeconomically grounded in material conditions defined by labour and technology, as well as the struggles around them. In capitalism, technologies are a means for and a chrystallization of the accumulation of capital. Under the control of the capitalist class, technologies are incorporated (as fixed capital, dead labour) into a system of exploitation that alienates workers, who in the factory become “a living appendix” of a “lifeless mechanism” which they themselves have created (Marx 1906, pp. 461–462). Capital and the capitalist class become autonomous (although surely not independent nor separate), labour and workers become heteronomous, while alienating technologies codify such situation, since they are subordinated to the former to subordinate the latter.

A century later, Jacques Ellul went beyond Marx in prioritising technology as a key sociohistorical factor and conceiving it as autonomous and value laden,[2] definitely turning the instrumentalist vision upside down. A long tradition had addressed the momentum, as well as the unanticipated, unintended or undesired consequences of technological systems, which defy instrumentalist optimism concerning both technology and human capacities for foresight, choice, or control (Winner 1978). But Ellul (1964) went beyond that in suggesting we live in a "technological society" where all rationalities, including the economic, are subordinated to a technical rationality defined by a drive for "absolute efficiency". Such technical rationality turns everything into a means and is unable to ponder ends. It subverts Kant's moral rationality, which sanctioned the role of human beings as autonomous, universal legislators. The Enlightenment's dream of instrumental reason (in Horkheimer and Adorno's terms) generated a modern monster, *la Technique* (no more the ancient *tekne*), a mass of methods, techniques, artifacts, forms of organization (e.g. bureaucracies, corporations), megasystems (e.g. chemistry, electricity, automotion, nuclear energy…) and their conditions (the means of the means) which, from 18th century onwards, have slowly become both material and normative conditions for modern society.

For Ellul, modern humans have willingly developed, and come to love and rely on, technological innovations and their benefits. However, the increasing number, scale, opacity, interdependency, interconnection and interpotentiation of those technologies has not only entrenched and made the total ensemble difficult to change, but has increasingly made it self-generating, self-determining and self-augmenting; ultimately, the key force defining the evolution of society. Only selected social groups (technicians, scientists, etc.) know and understand parts of such an ensemble, but not even them can do much to redefine it. For Ellul, technology has become anthropomorphic (e.g. self-determining) because humans have become technomorphic, externally enframed by the whole ensemble and internally reconfigured by its drive for rational efficiency and optimization. In what Winner (1978) calls a "reverse adaptation", those forms and ends of human life that fit within the ensemble, succeed, and those that do not, wither away. With Ellul, the unbridled development of the arts and sciences, which Bacon saw as a way to overcome the original sin, becomes itself the original sin of modernity.

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[2] Feenberg (1999) distinguished four key theories of technology: technological determinism (e.g. "traditional Marxism"), that conceives technology as autonomous (non-humanly controlled) and neutral (a means differentiated from ends); technological substantivism (e.g. Ellul), that conceives technology as autonomous and value-laden (a way of life that includes ends); instrumentalism, that conceives technology as humanly controlled and neutral; and, finally, critical theory of technology, which conceives technology as humanly controlled and value laden. This last position, which Feenberg defends, is connectable to our proposals in the synthesis section of this chapter. Meanwhile, technodeterminism and technosubstantivism are forms of what, in the current section, we are calling "technoautonomism".

Ellul stressed the autonomy of the technological ensemble at the macro-level, but others have attended to the micro-level of technical objects. Simondon (2017) provided arguments that allow to characterize technical objects as autonomous, as they develop through a process of concretization (functional and structural material integration), generating "evolutionary" lineages and essences that humans discover rather than create. In more Darwinian views, technical objects have been seen as units of evolution and humans as environments that select among them (Basalla 1988). Ironically, when technical objects become a systemic condition of society, there emerges the so-called "technological imperative", which demands not only to use them (as its most common understanding suggests) but also to adapt their environment (society and nature) to them to ensure their operation (Winner 1978). Against the Kantian categorical imperative, this new imperative seems to enshrine the growing autonomy of the technological and the heteronomy of the human. More recently, evolutionist leitmotivs can be found among authors such as Kurzweil (2005), who has crafted a history of the universe from the perspective of technical objects (specially, general artificial intelligence), culminating in a Technological Singularity where the human first recombines and then dissolves into an AI complex that grows and recrafts the whole cosmos. Less hyperbolic narratives also consider lower forms of AI and other technical objects (e.g. self-driving cars) as autonomous, mixing reality and myth in visions of humans either guided or substituted by machines (Bradshaw et al. 2013), in ways that sometimes recall debates on automation of the previous two centuries.

Finally, other analyses have attended to technological influence in psychological terms. Discussions about behavior-shaping technological environments have surfaced in contemporary behavioural economics and digital design, as in Eyal's (2014) guidelines for creating engagement or Thaler and Sunstein's (2008) concept of nudging as a design of the user's choice environment oriented to bring about a predictable change in behaviour. In this line, Zuboff (2019) denounced the rise of a surveillance capitalism where big digital corporations surveil and *surwill* (as labelled in Barandiaran et al. 2024; Calleja-López et al. 2018), that is, try to predict and shape users' behaviours to make a profit from it, thereby threatening moral and political autonomy. Ultimately, the "societies of control" heralded by Deleuze are defined by technologies oriented to shape the minds and habits of *dividuals* (the result of the datafication and decomposition of the modern individual) and their swarms (de la Torre et al. 2025).

All these philosophical views and historical processes have stressed the ascendancy and rule of technology (at various levels and in various forms, driven autonomously or by factors such as capital) over moral and political autonomy.

11.3 Synthesis. Technocomplexity: Reconstructing the Relations Between Technology, Morality, and Politics

Since the mid-twentieth century, different brands of cybernetics and their technologies, from servomechanisms to artificial life and intelligence, have focused on the integration of humanity and technology into increasingly complex and digitalized systems. Soon, the postmodern myth of the cyborg was born. Simultaneously, developments in paleoanthropology and philosophy went beyond Franklin's idea of the human as toolmaker and explored the relations of the human species and technology in terms of co-evolution and co-constitution: silex with cortex and hand (Leroi-Gourhan 1993), tools with language and sociopolitical norms (Birch 2021). Similarly, the extended mind thesis (Clark and Chalmers 1998) has gone beyond individualism and bio-centrism to highlight the role of technology in the constitution of the human mind, through dynamical relations that go from the sensorimotor (Pérez-Verdugo and Barandiaran 2023) to the institutional domain (Maiese 2026, this volume). Technologies are no more conceived as neutral instruments nor autonomous realities but as mediators in human-technology-world relations. These relations take a variety of forms –e.g. embodiment, hermeneutic, alterity, background (Ihde 1995), cyborg, composite (Verbeek 2008)– depending on which elements of the triad occupy the foreground or the background, resulting in different configurations of human interpretation, intentionality, action, and responsibility. Latour (2002, 2005) has suggested exploring the net-works of actants that, as quasi-subjects and quasi-objects, enter in a variety of associations to generate any form of self (*autos*), other (*allos*), and normativity (*nomos*). Going towards the spatial macroscale, Katheryne Hayles (2017) has examined global cognitive ecologies that entangle human and non-human actors in new collective forms of intelligence, decision, and action. Earlier, and still with modern undertones, Hans Jonas's (1985) "imperative of responsibility" to maintain genuine human life on Earth had widened the temporal and ecological horizons of analyses of technology. Together, these views contribute to a multiscalar ontological rethinking of autonomy (specially, of the *autos*) in the context of human-technology-world relations and human-and-non-human complexes and ecosystems; a third historical position that we may label "technocomplexity".

Bringing some of these insights into the field of morality, the ethics of design has mapped the variegated shaping of user behaviour –through coercion, decision, seduction or persuasion, depending on the strength and overtness of the influence– (Tromp et al. 2011). In the same line, it has questioned linear understandings of the influence of design intentions upon artefact utilisation by stressing the relevance of emergent and potentially unforeseen contexts of use (Albrechtslund 2007). Finally, as a complement, it has attended and proposed changes to the structural conditions of responsibility in design practice (Swierstra and Jelsma 2006).

But of more interest to us are political takes on technocomplexity. Langdon Winner convincingly argued that "artifacts have politics" and thereby connect to "ways of life". He showed that technologies are "politeia", "institutions in the making" that bring about a “second constitution” of society beyond the political-legal one (Winner 1986, pp. 54–55). For this reason, he stressed the potential of experiments in participatory design, and reclaimed new political virtues for this purpose (Winner 1992). Shared critical reflection by designers and users has been demanded (Sengers et al. 2005) as a way to unearth, analyse, choose and operate upon hidden or unconscious factors (e.g. cultural values or biases) shaping technology and its relation to human life. Meanwhile, recent calls for community-centred and intersectional approaches to technological design (attentive to discriminations based on ethnicity, gender, class, ability or other factors, and inclusive of affected groups and their interests) look to ensure more socially just technological artifacts and systems (Costanza-Chock 2020). Complementarily, the reflections of Donna Haraway (2016) and others (Driessen 2014; Cabello et al. 2026, this volume) suggest that such interventions should be careful, response-able and inclusive of non-human living beings, opening to a more diverse *autos*. Along these newly included actors, a diversity of values and virtues may be incorporated into design and use, a widening of *nomos* opposed to the absolutism of technical neutrality, efficiency, and proficiency. This may also challenge capitalism as a regime of universal heteronomy where, as Marx diagnosed, any principle, practice, or value is tendentially subordinated to exchange value.

Against Bacon’s technoinstrumentalist dream and Ellul’s technoautonomist nightmare, this third position suggests that technology should not dominate or serve to dominate humans and non-humans (old modern society and nature). Instead, new democratic technopolitical forms may appropriately involve those humans and non-humans (and their interests, values…) in the detection and framing of problems, the formulation of potential responses and the choice between those responses (which may or may not call for technologies as the way to advance), moving to the moments of technological design, development, and deployment, as well as the monitoring and evaluation of impacts, iteratively. This implies to recognize and productively incorporate the various scales of *autos* and *tekne* mentioned above, from the nano to the megascale, in both spatial terms (from *dividuals* to human-and-non-human orders, from the local to the global) and temporal terms (past, present and future, from the fleeting instant to deep time). This position critically builds upon earlier ones also by exploring the shapes, possibilities, and limits of technical knowledge (foresight and transparency but also uncertainty and opacity), control (flexibility and participation but also technological momentum and breakdown), intentionality (planning and assessment but also unintendedness and reverse adaptation), and value (fairness and justice but also biases and power contexts).

Building upon ontological, moral and political technocomplexity, this third position points towards a descriptive and prescriptive, empirical and normative, transformation of the modern *logos* around *tekne*. As an example, this may imply reducing technological complexity by opting for various forms of small, appropriate, low or slow tech in specific situations, and opting for big, high, fast and still appropriate technologies in others. In both cases, such technological options should incorporate autonomy (in the expanded sense –moral, political, ecological…– that we are outlining) as an ongoing precondition and as an ongoing result, as a central element in the complexes of principles and practices defining technological becomings. In digital societies built on top of multilayered stacks (of hardware, software, data, AI systems, etc.), to achieve this may require different cycles and forms of technopolitical democratization (Calleja-López 2021).

To sum up, the crucial form of autonomy in our technologically hypermediated world may be a recursive *technopolitical autonomy* that reflexively incorporates technocomplexity, taking the individual beyond itself, back to the ontotechnical and ecological constitution of its being, and forward into a personal and collective, ethical and political (careful, intersectional and mutispecific) participation in sociotechnical becomings. This is all to be considered at various scales, from concrete artifacts and people to wide megasystems and collectivities, with an orientation towards free, diverse and common forms of flourishing in the short, mid, and long term (Barandiaran et al. 2024; Chapter 5; Calleja-López et al. 2022, Sect. 5). New myths and makings will be necessary for such a struggle.

Acknowledgements XEB and MPV acknowledge IAS-Research group funding IT1668-22 from Basque Government, XEB, MPV and AC acknowledge grants PID2019-104576GB-I00 for project Outonomy and XEB and MPV PID2023-147251NB-I00 for Outagencies both funded by MCIU/AEI/10.13039/501100011033 and FEDER/UE. MPV is developing her PhD thanks to the Grant PRE2020-096494 of the Spanish National Research Agency (AEI) and cofunded by the European Social Fund.

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Chapter 12
Autonomy and Its Limits in Social-Ecological Systems

Violeta Cabello, Alejandro Merlo, María Mancilla, Jesús M. Siqueiros, and Xabier E. Barandiaran

Abstract Traditionally, autonomy has been perceived through the lens of individualism and internalism, a view increasingly challenged by contemporary philosophical approaches, as well as by the context of global sustainability. Environmental challenges underline the need to shift from Earth-imposed limits to social-ecological limitations to achieve autonomy, democracy, and sustainability. In the realm of sustainability sciences, the concept of social-ecological systems has been developed to explore the interdependencies between humans and their environments. Despite the significance of autonomy in discussions around sustainability, its exploration within this field remains limited. This chapter aims to discuss the potential contribution of the concept of outonomy for social-ecological systems and the planetary scale and, conversely, to open up the concept of autonomy to planetary-ecological dependencies.

Keywords Social-ecological systems · Earth limits · Gaia · Social-ecological outonomy

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X. E. Barandiaran and A. Etxeberria (eds.), *Outonomy*,
SpringerBriefs in Philosophy, https://doi.org/10.1007/978-3-032-05501-9_12

> The need to "stay with the trouble," (…) Such concern is what enables me to discern, and cast my lot with, a new understanding of autonomy as the invention of ways of living, not just surviving, in the ruins—whatever the final outcome.
>
> STENGERS, 2017

12.1 The Modern Notion of Autonomy and Social-Ecological Thinking

The concept of autonomy, defined as a system's capacity to govern itself through self-generated norms, is central to Western modernity. Its use spans biology (Varela 1979; Moreno and Mossio 2015), psychology (Legault and Inzlicht 2013), moral philosophy (Mele 1995), and social and political theory (Castoriadis 1991; Hardt and Negri 2005; Zibechi 2007). However, autonomy has traditionally been seen as confined within the boundaries of the individual or social system in an abstract, rationalistic, self-sufficient manner (see Barandiaran and Etxeberria 2026, this volume). The received notion of autonomy has been questioned across disciplines, from individual agency to societal scales (Armstrong et al. 2019). Still, nothing seems to challenge its core precepts more than crossing the boundaries of environmental sustainability on a planetary scale (Rockström et al. 2009).

While Earth's conditions set material boundaries for the material expansion of human societies, capitalist economies seem to defy external limits. The issue then is how to transit from limits determined by Earth's life-sustaining dynamics to self-imposed limits as a condition necessary for autonomy, democracy (Castoriadis 1991; Kallis 2019), and sustainability. Feminist scholars—including those in new materialisms or posthumanisms—critique the view of autonomy as the self-production of a self-sufficient individual (Haraway 2016; De La Bellacasa 2017; see also Urdangarin & Umerez 2025). They call for recognizing interdependencies and caring relations as the foundation for existence and social-ecological thriving. While we agree with this call, these criticisms address only a narrow view of autonomy—one that has been enriched by relational and enactivist perspectives, as discussed in the next section.

With Stengers (2017, p. 398), in this text, we seek to *reclaim* a new understanding of autonomy that enables "the invention of ways of living, not just surviving, in the ruins". We argue that an updated notion of autonomy that applies to the Earth system is critical at both descriptive and prescriptive levels: the former to better conceptualize the complex adaptive potential of beyond-the-individual social-ecological assemblages (Spies and Alff 2020); the latter to improve the promotion of the ensuing response-ability (Haraway 2016) that such a conceptualization brings forth.

12.2 Autonomy and Interdependence in Life and Mind

The concept of autonomy has been developed in biological and cognitive sciences through the legacy of Maturana and Varela's notion of autopoiesis (Maturana and Varela 1980). The original focus on operational closure has progressively led to a thermodynamically open (Ruiz-Mirazo and Moreno 2004), adaptively agential (Barandiaran et al. 2009), interactively constituted (Gallagher 2020) and social-ecologically interdependent conception (Escobar 2018). At its root, the autonomy of life is the capacity of living organisation to sustain itself (far-from-equilibrium in the face of a continuous flow of matter and energy) as a network of production and repair processes (metabolism) while differentiating such a network from an environment it, nevertheless, depends upon. The paradigmatic example is the cell: absorbing molecules from the environment to feed its metabolic reaction network, while producing a membrane that encapsulates the network and mediates with the environment. In doing so, the cell defines a set of viability *norms* (requirements to keep itself alive: temperature, nutrient input rate, etc.) and a *self*: an individual produced and kept distinct from its environment. Yet, as Hans Jonas put it, the relationship with the environment is not an opposing or purely self-differentiating one but one of "needful freedom" (Jonas 1966).

Enactivism has extended this concept of biological autonomy to the cognitive domain (Di Paolo et al. 2017; Varela et al. 1991). Far from the Kantian self-sufficiency of encapsulated reason to guide behaviour, sensorimotor autonomy implies a radical openness to the environment to constitute mental processes as interactive structures (sensorimotor coordinations, habits, activities, etc.). A fundamental dimension of this openness is linguistic sociality. It is constitutive of human autonomy, leaving it open to a world participated by and with others (Di Paolo et al. 2018). In fact, many worlds, some from an indigenous and decolonial stand, reclaim a deep sense of autonomy rooted in earthly social-ecological communal forms of life (Escobar 2018). In human life, as we know it, that kind of autonomy can only be realized through a deep understanding of the concept that includes political participation in radical democracy and the material limits of the Earth system (Asara et al. 2013; Castoriadis 1991; Maiese and Hanna 2019).

The notion of autonomy is therefore understood as (re)emerging in different domains or scales: the molecular-metabolic, the multicellular, the neurobehavioural, the sociolinguistic, the political and the social-ecological. However, this last one has, surprisingly, attracted little attention from the complex systems approach to autonomy and ecology. Some notable exceptions build a concept of function in ecosystems in analogy with that of organismic function (Nunes-Neto et al. 2014) or, by drawing inspiration from (Clarke 2020) or in conflict with (Haraway 2016), the autopoietic or autonomous concept of organism at ecological and planetary scales. And yet, the study of social-ecological systems is constituted by some of the ingredients essential to the bio-enactivist concept of autonomy.

12.3 Autonomy and Social-Ecological Systems

The concept of social-ecological systems (SES) emerged in the field of sustainability sciences to study human–environment interdependencies (Berkes and Folke 1998; Berkes et al. 2003; Anderies et al. 2004). Rooted in complex systems theory and theoretical ecology, SES are defined as complex adaptive systems (Folke et al. 2016) comprised of intertwined social and ecological constituents (Schlüter et al. 2020). SES self-organize, producing emergent rules and patterns (Ostrom 1992; Aggarwal and Anderies 2023; Schlüter et al. 2019), and are viewed as open networks linking local and global scales (Laroche et al. 2020). Although autonomy is not explicitly studied in SES, we identify features that support an expanded, relational understanding of the concept, with the goal of conceptually integrating and enriching these different research traditions.

The field of SES research has evolved over time along with the development of theoretical perspectives and through their variegated applications (Colding and Barthel 2019). Early definitions viewed social and ecological systems as separate entities, with the social constituent self-organizing according to its own institutions aimed at governing the environmental constituent (Berkes and Folke 1998). The idea of *adaptability* was central to these early conceptions, together with that of resilience, formulated as the capacity of a SES to navigate change without substantially compromising its functions (Berkes et al. 2003). Following this, Gunderson and Hooling (2003) defined the *adaptive cycle* as periodic shifts from stability to transformation driven by non-linear interactions, implying that SES both persist and adapt through time.

One of the most significant evolutions in the study of SES is the concept of *intertwinedness,* which shifts the conception of the social and the ecological as separated elements to a co-constituted view of SES through continuous processes of intra-action (Schlüter et al. 2020). Social–ecological phenomena—such as a fishery collapse or a forest's spiritual value—emerge from multi-level, evolving relations among humans and other entities (Schlüter et al. 2019). This view resonates with the process interdependence view in organizational and enactive accounts of autonomy.

Normativity and *viability* are fundamental notions in both the autonomy and SES fields. However, these two traditions hold different understandings of these terms. As outlined in the previous section, norms in autonomy are conceived as behavioural or physiological preferences, constraints or regulations over multiple available possibilities that emerge from the activity of the system, directed to maintain itself within viability limits or to expand those limits (e.g. to regulate the temperature within survival ranges in an animal or pump ions at a given rate to avoid an osmotic crisis on a cell). This conceptualisation resonates with research on the ecological side of SES, where, for example, diversity in the trophic networks has been shown to be fundamental for the viability of ecosystems. Nevertheless, the most common understanding of norms within sustainability sciences is inherited from social scientists' contributions to the field, that is, as social-institutional norms: formal or informal rules created by social actors to regulate and act upon social-ecological dynamics.

Various schools have studied how norms are socially created and enacted, from Elinor Ostrom's studies on local common pool resource management to more ample studies on environmental policy and adaptive, collaborative or multi-level governance (Ostrom 1992; Emerson et al. 2012; Newig and Koontz 2014). Contrary to norms in autonomous agents, regulatory aspects in SES permeate different organizational scales and levels of abstraction and concretization: from policies and laws dictated by external regulatory institutions (e.g. the EU) to the practical application and integration of such norms in the different contexts, or the concrete "needs" and practices of forms of life in SES.

The challenge lies in moving from norms conceived as purely socially contingent to norms as social-ecologically intertwined. The SES literature is only recently addressing this integration of social and ecological norms. For instance, Schlüter et al. (2019) distinguish between social norms and biophysical rules and structures (such as food webs or climatic conditions) in determining social-ecological phenomena. Another example is how Aggarwal and Anderies (2023) link cultural theory and SES analysis to advance a conceptualization of governance as emergent social-ecological feedback structures that enable a fine-tuning of SES relations. If we adopt the definition of norms put forward in enactive accounts of autonomy, we could further argue that a social-ecological norm establishes the viability limits of SES as an autonomous system and ensures its ecological and social long-term sustainability.

The enactment of such a norm requires defining viability limits for social-ecological intra-actions within the boundaries of each SES, which leads to the problem of many SES not having clearly delineated frontiers. For example, where to set the border of a fishery or a natural protected area is a difficult governance and analytical question. This type of decision is not trivial, as illustrated by the ample literature discussing how to 'fit' social and ecological boundaries (Moss 2012) and whether these boundaries are 'real' or 'constructed' according to particular analytical goals, scales, and methods (Wu 2013).

Another key point is that SES are open systems and thus their metabolic relations (such as food production, fishing, transport, mining, fuel extraction or consumption of technologies) are always open and integrated across multiscale production chains that partially determine local practices and regulations (Giampietro et al. 2011; Laroche et al. 2020). For this reason, it would be particularly hard to define their limits in the form of an organizational or operational closure. As IPBES (2024) has bluntly put, in global capitalist economies, the capacity of the multitude of SES on Earth to redefine what is good, viable and sustainable for (and by) themselves, create their own response-able norms and care for their intra-actions is nowadays hampered.

This last problem of establishing the boundaries of SES brings us to the level of the whole earth as the ultimate SES and anchor of autonomy.

12.4 Gaia: Social-Ecological Autonomy at the Planetary Scale

The concept of Gaia—viewing the Earth system as a living entity (Kleidon 2023; Lenton et al. 2020; Lovelock and Margulis 1974)—represents a convergence point between theories of biological autonomy and socio-ecological systems (SES). This perspective challenges the conventional dichotomy between living organisms and their environments (Etxeberria 2026, this volume), proposing instead that they form integrated, self-regulating entities. In this expanded framework, life is not confined to individual organisms but emerges from the collective activities of living systems and their interactions with their surroundings, including atmospheric and geological processes over long timescales.

James Lovelock and Lynn Margulis initially articulated Gaia theory by suggesting that Earth's atmospheric composition is regulated by living processes, akin to how an organism maintains homeostasis (Lovelock and Margulis 1974). Margulis, in particular, emphasized the self-creative nature of life through her engagement with autopoiesis, influenced by Francisco Varela. Her work argued for biology's independence from reductionist paradigms in physical and molecular sciences, asserting that the simplest autopoietic entity is the bacterial cell and the largest is Gaia itself (Lovelock and Margulis 1974; Clarke 2020). This view situates Gaia within a continuum from cells to ecosystems, emphasizing cooperative and symbiotic processes as foundational.

Two main challenges have been raised against a conception of Gaia rooted in biological autonomy. Building on Margulis's insights, Haraway and others have advocated for shifting from autopoiesis to sympoiesis, emphasizing symbiotic collaboration (Dempster 1998; Haraway 2016). While the term sympoiesis highlights the central role of symbiosis in life, we argue that it complements rather than replaces autopoiesis. Biological autonomy continues to provide a critical framework for understanding the integrity of individual cells and the organized, systemic nature of Earth as an 'ecosystem of ecosystems'. Latour, on the other hand, critiques Gaia theory's cybernetic roots, suggesting that such frameworks impose reductive, top-down, and engineering-centric perspectives (2015: 78, 81–83). However, this critique overlooks advances in second-order cybernetics that challenge the separation of observer and system, emphasizing their co-dependence (Clarke 2020). These developments align with contemporary theories of biological autonomy, offering a non-reductive, bottom-up approach that recognizes Gaia not only as self-organizing and inherently resistant to external control but also precarious and vulnerable to malfunctioning and "disease".

The climate crisis is a manifestation of this autonomy being challenged. It brings to the surface that there are some "norms" at a planetary level that have been broken, that something is "malfunctioning" (Rockström et al. 2009). Any discussion about SES sustainability and autonomy is thus necessarily enmeshed with that of global sustainability. Moreover, the possibility of autonomy of local SES, at the scale of certain human-cultural-ecosystemic life-forms (like those of indigenous social-ecological systems), might be about to get irreversibly lost in the capitalocenic acceleration. This acceleration is bringing planetary scale autonomy (Gaia) down to the human scale of SES, rapidly merging the pace of local SES with that of the planetary scale.

Ultimately, here is the paradox: the modern category of autonomy, encompassing biological, moral and political spheres, as that of an independent self-governing individual, cannot find any satisfying member other than the Earth system itself. This is the only form of living existence that, floating in the void, only depends on the energy of nuclear reactions of the sun and the planetary nucleus. Below this, we are deemed to live outonomously, that is, acknowledging and bringing forth our deep mutual interdependence with the environment we produce, and we are part of, together with other living and non-living entities.

12.5 Conclusion

Global warming, the loss of biodiversity or the acidification of the oceans call into question the individualistic vision of self-regulation and self-sufficiency that the modern conception of autonomy brought with it. It forces us to think that if the concept of autonomy has an ontological, epistemic and normative value, it is because it is necessarily relational, non-anthropocentric, and increasingly open to include larger scales of caring. We have argued that an updated notion of autonomy, as developed in organization and enactive traditions to the philosophy of biology and mind, can meet contemporary trends and can contribute to identifying limits, norms and regulatory capacities in SES research. Furthermore, we posit that it is even crucial in order to enhance our capacity to design for (Escobar 2018), to commit to and to inhabit more sustainable shared forms of life, ultimately encompassing the whole earth as an autonomous form of life.

Acknowledgements XEB and AM acknowledge IAS-Research group funding IT1668-22 from Basque Government, grants PID2019-104576GB-I00 for project Outonomy and, together with VC PID2023-147251NB-I00 for Outagencies funded by MCIU/AEI/10.13039/501100011033 and FEDER/UE. VC has been funded by the Spanish Ministry of Science and Innovation Ramón y Cajal (RYC2021- 031626-I) and María de Maeztu (CEX2021- 001201-M) programs, and by the Basque Government BERC 2022-2025. MMG acknowledges the Swedish Research Council (VR) under grant number 2018-05792.

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Chapter 13
From Self-Sufficient Individuals to Subjects-In-Common

Mikel Urdangarin and Jon Umerez

Abstract The aim of this chapter is to review the criticism of the self-sufficient individual and to consider how autonomy can be thought from the subjects-in-common. As Goikoetxea affirms, “one is not born a subject, it is made”. Subjects are not autonomous owners of themselves. Instead, they are constantly overcome and dispossessed by the relationships that constitute them. If the subject is made and determined, how can autonomy be thought of? Our hypothesis is that being determined, done and dispossessed, is a precondition for autonomy instead of an external limit to it, although it is not a guarantee. The question is how to determine it. The question is not, therefore, whether one has or does not have links, but about what kind of links one has. In conclusion, against the model of autonomy understood as a pre-social property of a self-sufficient individual, we propose an alternative model of autonomy: a situated and plural capacity for self-governance developed within, through, and against social relationships.

Keywords Subject · Autonomy · Self-sufficiency · Interdependence · Common

13.1 Introduction

Adapting De Beauvoir’s famous dictum, and synthesizing decades of philosophy from Foucault to Butler, Jule Goikoetxea states that “(o)ne is not born a subject, it is made” (2017). She summarizes this way the thesis that the subject is not the autonomous owner of itself, but is constantly overcome and dispossessed by the relationships that constitute it.

But, if the subject is made and, accordingly, determined, how can autonomy be thought of? Does being produced deny us the possibility to act? Is autonomy

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X. E. Barandiaran and A. Etxeberria (eds.), *Outonomy*,
SpringerBriefs in Philosophy, https://doi.org/10.1007/978-3-032-05501-9_13

possible in this dispossession? Our hypothesis is that *being determined, done and dispossessed, instead of being an external limit to autonomy is a precondition for it, even if not a guarantee.* The question is, then, how the subject is determined and made. The question is not as much whether to have links or not, as the debate is frequently introduced, but what kind of links they are.

In order to explain this, we will divide the chapter into three sections: first, we will review the criticism of possessive individualism (Macpherson, 1962); second, we will introduce the notion of subjects-in-common; third, we will consider how autonomy can be understood under this form of subjectivity.

13.2 Critique of Possessive Individualism

Advocates of the notion of *subjects-in-common* have based their model of subject on a straightforward criticism of possessive individualism. According to the theorists of the social contract, i.e. Hobbes, Locke or Mill, every 'man' was free and equal by birth and nature. The free choice of the individual was the main specificity of the modern world and, therefore, the subject could no longer be definitely predetermined from birth in a situation and place. The authors and the axes of the social contract had to be the autonomous individuals. As Pateman characterizes it:

> [The contractarian individual] is seen as naturally complete himself. That is to say, the boundaries that separate one individual from another are so tightly drawn that an individual is pictured as existing without any relationships with others. The individual's capacities and attributes owe nothing to any other individual or to any social relationship; they are his alone. The contractarian individual necessarily is the proprietor of his person and his attributes, or, in C. B. Macpherson's famous description, he is a possessive (Pateman 1988: 55).

In this sense, the contractarian individual was *self-sufficient*, such that he was sufficient to exist by himself; *pre-social*, as constituted before any social relation; and *possessive*, developing the relations and contracts in order to protect his property from the perspective of his self-interest. In short, as a proprietor of his property, his conscience, and his relationships, he was sovereign of himself or, as Locke put it, "every individual man has a property in his own person; this is something that nobody else has any right to" (Locke [1690] 2017: 11) And also, for instance, Mill states that "In the part which merely concerns himself, his independence is, of right, absolute. Over himself, over his own body and mind, the individual is sovereign" (Mill [1859] 2004: 37). The autonomy, therefore, was pre-social and the social contract was the instrument to secure it: "The great purpose for which men enter into society is to be safe and at peace in their use of their property; and the great instrument by which this is to be achieved is the laws established in that society" (Locke 2017: 43).

But, according to Gil, this ideal of autonomy is built on the three fallacies (2014: 298–299). Firstly, it is based on the denial of the collective dimension of existence, privatizing the sense and intentions of life. Secondly, it is based on the idea that consciousness is sufficient for itself to be, as if knowing oneself were possible without the interpellation and mediations of others. In this sense, and lastly, it affirms self-sufficiency, denying physical, corporal and social bonds and concealing the care work they demand within the sexual contract.

As a preliminary conclusion, then, we claim that the possessive and self-sufficient individual is not sustainable (see also Cabello et al. 2026, this issue). It is based on the invisibility and exploitation of the works and relationships that make life possible. That supposed universal subject is very particular: a heterosexual, white, bourgeois man who speaks the hegemonic language. Subjects need to be thought differently.

13.3 Subjects-In-Common

Diverse feminisms have drawn a different kind of subject built from the previously outlined criticism. As Goikoetxea says, we are not born subjects, but mammals. Men, women, basques, whites, workers, or bourgeois… the subject is done a posteriori (Goikoetxea 2017: 275). How to understand that "doing"? Since we cannot deal with an exhaustive analysis of every author that has attempted to answer this question, we will focus here on some contributions by Butler and Haraway.

In Butler's opinion the sovereign subject is dangerous, and it must be displaced. To do so, she proposes, as an alternative, the notion of dispossessed and precarious subjects. This concept moves, not only beyond standard approaches to autonomy, but also beyond simple relational ones: "Despite my affinity for the term relationality, we may need other language to approach the issue that concerns us, a way of thinking about how we are not only constituted by our relations but also dispossessed by them as well" (Butler 2004a: 24).

She underlines three characteristics: First the subject is made in common, under certain material and symbolic conditions, responding to the interventions and interpellations of others. The subject is not foundational, because in order to be able to do, it has to be done before, socially. Others touch us, feed us, take care of us, place us in a discourse and a language, establish specific social norms for recognition, etc. This object of care, languaging, and normalization only emerges later as a subject, always in a limited way: "we are, from the start, given over to the other, one in which we are, even prior to individuation itself and, by virtue of bodily requirements, given over to some set of primary others" (Butler 2004a: 31). In this sense, it is not self-sufficient, it is conditioned and mediated by norms, discourses and social supports. Consequently, the "I" is not a presocial entity or a substance. On the contrary, the "I" is a set of relations and processes immersed in a world that goes beyond the individual. We cannot escape from that shared condition. These relations make us.

Secondly, these relationships not only shape us, they dispossess us too. The relations and processes that cross the subject make it partially opaque to itself. The subject is limited and not transparent, because the narrative "I" cannot fully explain and control its formation, even less in first person: "I may try to tell the story of myself, but another story is already at work in me, and there is no way to distinguish between the 'I' who has emerged from this infantile condition and the 'you'—the set of ‘you’s’— who inhabits and dispossesses my desire from the outset” (Butler 2005: 74). This inscrutable condition cannot be fully explained, though it cannot be avoided. That opacity must be constant before it is cleared up. In this sense, the subject is not entirely coherent either, because while they make us, they decentre and disorient us. Instead of possessive individuals, we are dispossessed subjects, because the links that form us partially are the same ones that prevent the self from being totally mine. In that sense, the subject is incomplete and open-ended.

Thirdly, the subject is permeable and vulnerable. This close dependence on previous and cross-sectional links makes us not only dependent but vulnerable: we are not in our hands, we are dependent and vulnerable to what is not ours. These primary relationships not only shape and support us, but also limit us, threaten us and exclude us, making us vulnerable to the recognition, contact, intervention and violence of others: “our being socially constituted bodies, attached to others, at risk of losing those attachments, exposed to others, at risk of violence by virtue of that exposure” (Butler 2004a: 20). Accordingly, she makes a difference between precariousness and precarity. Precariousness is an inevitable and common dimension of bodily life. However, precarity is an evitable and differential redistribution of that shared precariousness according to political and social conditions.

Butler, therefore, calls into question the self-sufficient, sovereign, coherent, transparent and pre-social subject. The subject is, in her view, the articulation of a set of relationships and processes. It is vulnerable, incomplete, contradictory, profoundly implicated in the lives of others. In short, it is a precarious and dispossessed subject.

Going deeper, Haraway also invites us to think of the subject in another way: “refigure the kind of persons we might be. These persons can no longer be, if they ever were, master subjects, nor alienated subjects, but—just possibly—multiply heterogeneous, inhomogeneous, accountable, and connected human agents” (Haraway 1991: 3). To elaborate this, she has proposed some interesting metaphors. On the one hand, in the face of *autopoiesis* she proposes *sympoiesis* and “become-with” (Cabello et al. 2026, this volume). We become who and what we are with others, in those sympoietic relations. Without a prior essence, the subjects form themselves in these relationships in a continuous process: they are “coconstitutive relationships in which no partner will preexist the relationship, and the relationship is never done once and for all” (Haraway 2003:12). Following Barad (2007), Haraway suggests in a more recent book (2016) the category of intra-action to explain this. It’s not an interaction between complete units. On the contrary, the units are completed and constituted in those relations.

In turn, Haraway extends the scope of dependence and intra-action. By linking “humanus” with “humus” (earth), she expands this intra-action into *humusities*. That is, in complex, continuous and dynamic assemblages, associated with non-human subjects. In this sense, she emphasizes that human beings and other beings exist in a shared compost, underlining the ecodependencies in her idiosyncratic style: “human beings are not in a separate compost pile. We are humus, not Homo, not anthropos; we are compost, not posthuman” (Haraway 2016: 55). Immersed in humusities, the subjects became-with in these multiple sympoietic and intra-active relationships. Using her metaphor, the subjects are *companion species*.

However, this common compost is not a holistic, benign and harmonious Mother Earth. It's not the idyllic Other that needs to be rebalanced. In Haraway's words, nature is a "coding trickster with whom we must learn to converse" (1991: 201). Since the world is "a knot in motion" (2003: 6), it is a complex, heterogeneous, contradictory, contingent and often unpredictable assemblage, which is made through social, cultural and ecological interactions. Besides, among these non-linear connections, these socioecological interconnections are necessarily partial and situated: "nobody lives everywhere; everybody lives somewhere. Nothing is connected to everything; everything is connected to something" (Haraway 2016: 31). In this sense, the subject is situated.

Therefore, different authors have profoundly revolutionized the idea of a presocial individual. The following conclusions can be drawn from these criticisms and their alternative approaches. On the one hand, the subject and autonomy, more than the foundational starting point, is rather the incomplete product of many works and processes. On the other hand, interdependence/ecodependence is not a network of relations that is tied up later by the presocial subject, but a primary and permanent condition that configures us as a subject. Finally, these dependencies not only make us, they also dispossess us. Consequently, the subject can no longer be represented as self-sufficient, transparent and complete. It is a concrete articulation of a set of relationships and processes, incomplete, contradictory and heterogeneous. We will use "subjects-in-common" (Llaguno 2018: 72) to express that kind of subject.

13.4 Autonomy in Terms of Relationality

Given the common and precarious dimensions of our lives, how can we rethink autonomy? We do not have to choose in terms of the classic alternatives, between the liberation from ties or the conformity to ties. Whether they propose the union or the separation, both of the approaches presuppose a presocial subject. Garcés revolutionizes this starting point asking: "What if the bodies are not united or separated? Beyond the duality union / separation, the bodies continue each other' (Garcés 2013: 30). Immersed in humusities, the question again is not whether to have links or not, but what kind of links exist in such a continuity. Here is the tension: in the face of the fantasy of breaking off the links, the subject will have to be liberated within the links, by making the links more liberating. Garcés expresses this creative tension thus: "this life, which is not mine, is mine" (2013: 150). Also this is the space where the notion of *outonomy* explored in this book is situated (Barandiaran & Etxeberria 2025, this volume).

But how do we do it? In this respect, the next question emerges. If the subject is made and determined, how should one think and exercise autonomy? Does having been done deny us the possibility of doing? It doesn't have to be that way. To have the capacity to act, the subject must be capacitated to act. In other words, in order to act ourselves, others have to act on us. Although it may seem paradoxical, we can only individualize ourselves in sociality: “The self must, in this way, be dispossessed in sociality in order to take possession of itself” (Butler 2004b: 7).

Therefore, the fact that they have done us does not exclude the possibility of doing. But it doesn’t even guarantee it because those relations also undo and disable us. So, what to do? “What can I do with the conditions that form me? What do they constrain me to do? What can I do to transform them?” (Butler 2004a:16).

To make mine what is not mine, we will have to get involved in what is not mine or, in other words, in what is common. More specifically: within, through and against those links. *Within*, because there is not a ‘pure’ body outside the relational assemblage and power relations that cross it. *Through*, because through the same disciplinary and biopolitical mechanisms that modulate us and condition us, the subject is made and enabled to act. For example, we have to go through a process of domestication to learn how to read and write, which is essential for democratization. Finally, *against*, because those links not only capacitate and sustain us, but they also subdue us and threaten us by redistributing vulnerability in a differential way. The politicization and transformation of these links is therefore also fundamental. The maintenance of this tension is essential, as we are subjects in the ambivalence between the affirmation and problematization of those relationships. In other words, in the tension between subjection and subjectivity.

This forces us to understand autonomy differently. Firstly, autonomy must be understood as a capacity rather than as a property. Autonomy is no longer the originative property of the possessive individual, who must be the object of negotiation, guarantee, or delimitation a posteriori. It cannot be a pre-social property because we are dispossessed from the very beginning. In the face of this, in Goikoetxea’s approach, it is the sociopolitical capacity for self-governance that matters, one that can only develop in concrete socioecological conditions. Precisely, it is the territorialized and institutionalized capacity of self-governing according to one’s own decision (Goikoetxea 2017). In other words, the capacity to be equally free: that is, to be capable (free) and as capable as the most capable (equal) to self-govern our lives. Or, rather, a constant social process to capacitate, since it is a relation and not a thing.

Besides, it must be understood in plural rather than in singular. If the autonomy is relational, that autonomy must be extended to all relations that cross life. On the road to democratisation, Olariaga proposes the representation of autonomy as a polyhedron (Olariaga 2020: 83). In this sense, more and more authors speak about autonomies, in plural form. Bodies, lands, energy, communities, data, livelihoods… In short, it is claimed that autonomy is about all the dimensions of life(s). In turn, as those shared lives are situated in concrete ties, autonomy will also have to materialize in these situated interrelations, according to its limits: “A common livable world must be composed, bit by bit, or not at all” (Haraway 2016: 40).

Hence, de-democratization occurs when that socio-political capacity of self-governance is privatized and disabled. On the contrary, democratization may consist in the expansion and equalisation of that capacity.

In the Basque Country we have many examples of vindications of plural and situated autonomies. This is evidenced, for example, by the autonomy (“burujabetza”, in Basque) model claimed by the movement *Bizi!*. On the one hand, it is plural, because every dimension that goes through life is taken into account: energy, care, nutrition, body, housing, language, economy, culture… In a polyhedral way, the intention is to articulate and strengthen each other: "We will regain possession of the conditions of our lives according to models adapted to each area of life, which will inspire and reinforce each other" (Bizi 2018: 7). On the other hand, it is territorial, because it is located in the (Northern) Basque Country, and they claim to return to the territories: "It is time to put our feet back on the ground, in the territories of which we are a part, to make them live up to the challenges of this very crucial period, by regenerating the links which have been damaged" (Bizi 2018: 9). Thus, within, through and against these links, the goal is to build a sovereign, sustainable and solidary territory and "to take possession of living conditions again" (Bizi 2018: 1).

13.5 Conclusions

We can therefore draw three main conclusions.

1. The subject and autonomy are, rather than foundational premises, open-ended and differential productions of many works and processes. Immersed in social and ecological assemblages, the subject should be understood "in common".
2. As subjects-in-common, the question is not to have links or not, but what kind of links, as we have repeatedly defended. We will have to liberate ourselves within the links, by making those links more liberating. This is a creative tension.
3. This requires redefining autonomy. It is no longer a pre-social property. On the contrary, it must be understood as a process of capacitation developed within, through, and against social relationships. Specifically, understood in these terms, in the socio-political sense, autonomy is the situated and plural capacity to self-govern our lives.

That is the challenge: the expansion and equalisation of that capacity. That is, to take possession of oneself in the dispossession. To make our lives, which are shared and not ours, ours.

Acknowledgements The authors acknowledge IAS-Research group funding IT1668-22, from Basque Government, and grants PID2023-147251NB-I00 and PID2019-104576GB-I00 for projects Outonomy and OUTAGENCIES, funded by MCIN/AEI/10.13039/501100011033. Mikel Urdangarin acknowledges the grant and funding by the Joxe Azurmendi Katedra, EHU.

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Chapter 14
Mindshaping and Adaptive Preferences

Michelle L. Maiese

Abstract Agents with adaptive preferences participate readily in oppressive social practices, even when doing so is in tension with their broader interests or overall well-being. To make sense of the way in which social influences sometimes undermine agency, I look to enactivist notions of embodied habit and mindshaping. Adaptive preferences should be understood as habit bundles that result from covert social influences, become rigidly engrained, and signify a localized autonomy deficit.

Keywords Adaptivity · Enactivism · Habits · Socialization

14.1 Introduction

By way of socialization and enculturation, agents are deeply molded by their social environment, often without even being self-reflectively aware of it. One phenomenon that reveals the potentially pernicious impact of socially-inculcated values and attitudes is adaptive preferences (AP's) (Elster 1982); social and political philosophers have used this term to highlight instances in which members of marginalized groups come to desire "that which is oppressive to them" (Cudd 2006, 181) because satisfying such desires confers social advantages. To make sense of how social influences can undermine autonomous agency, I look to enactivist notions of embodied habit and mindshaping. By way of social coordination, habit formation, and the embodied internalization of norms and expectations, agents are mindshaped by their environment. Such mindshaping can be primarily enabling or destructive, depending on the nature of the habits it cultivates. Because agents are embedded in a social environment, they are vulnerable to being molded in pernicious ways. AP's can be understood as habit bundles that form in response to dominant practices, help agents adapt to their social surroundings, and yet also prove to be harmful. To make sense of such harms, I propose that AP's encompass embodied habits that (1) result from necessarily covert social influences, (2) are in tension with an agent's broader network of

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X. E. Barandiaran and A. Etxeberria (eds.), *Outonomy*,
SpringerBriefs in Philosophy, https://doi.org/10.1007/978-3-032-05501-9_14

interests, intentions, and values, and (3) have become rigidly engrained. Conceptualizing APs in enactivist terms helps to naturalize these disruptions to agency and also reveals autonomy's important relational dimension.

14.2 Adaptive Preferences as Localized Autonomy Deficits

Feminist philosophers have argued that in a world where some expectations and norms support unjust and inegalitarian social systems, someone's social surroundings "can effectively socialize [them] to prefer conditions or options that are bad for [them]" (Terlazzo 2016 206). Consider, for example, a woman who wants to undergo breast augmentation to make herself more attractive, or a man who refuses to seek treatment for depression because he takes this to be in tension with masculinity. The concept of adaptive preference (AP) has value because it does "political work": it allows philosophers to oppose the claim that "women's enjoyment of sexist practices makes such practices morally and politically unproblematic" (Khader 2012, 303).

While theorists tend to agree that people's preferences can be molded in pernicious ways, they disagree about (a) whether these preferences signify an autonomy deficit, and (b) whether use of the concept of 'adaptive preference' will result in disrespectful modes of treatment. If those who perpetuate their own oppression are viewed as irrational or cast as "dupes of patriarchy" (Khader 2012, 302), will this legitimize paternalistic intervention or coercion? Terlazzo (2016) proposes that "rather than choosing between using the concept of adaptive preferences and showing persons respect, we should aim to do both" (210). Although the concept can function as a valuable tool for combatting marginalization, by explaining which preferences deserve to be scrutinized, it also is important to exhibit appropriate consideration for people's agency.

An adequate account of AP's needs to explain what makes them simultaneously both "adaptive" and detrimental to a person's well-being. Feminist philosophers have noted that on the one hand, these preferences are beneficial in the sense that they help people to survive, whether emotionally or physically, in circumstances that are beyond their control (Bruckner 2009). On the other hand, they often involve disruptions to autonomous agency and result in behavior that is in tension with an agent's broader interests. However, because it is doubtful whether any human agent can exercise this capacity fully in every domain of their lives and at every moment, it would be a mistake to view autonomy as an "all-or-nothing property" of a person's whole life (Christman 1991, 3). Instead, we should distinguish between (i) possessing a general capacity for autonomy, and (ii) being able to exercise it fully at a particular time. AP's signify a *local* disruption to agency rather than a *global* disruption in the capacity to exercise autonomy.

Casting AP's as localized autonomy deficits "allows that people can perpetuate their oppression and retain critical attitudes toward some norms" (Khader 2012, 308). Because individuals in oppressive contexts often retain a normative perspective and find ways to actively bargain with their situation, it is problematic to view them simply as "victims" of oppression. To show "recognition respect" to such agents requires that we give proper weight to the fact that they are *persons*, i.e., that they are capable of some degree of self-governance (Darwall 1977, 45). Paternalistic modes of intervention (for example, forbidding women from acting on their desire to veil in public or bind their feet) would constitute a failure to respect their autonomy. Can concepts drawn from enactivism shed light on APs?

14.3 Enactivism, Habits, and Mindshaping

Enactivism emphasizes that cognition is fundamentally relational, environmentally situated, and bound up with the dynamics of living systems (Weber & Varela 2002). To regulate themselves and respond selectively to their surroundings, living organisms do not passively form an internal representation of things in a pre-given world, but instead actively "bring forth" (i.e., enact) a unique cognitive domain. By way of "sense-making" (Thompson 2007), they gauge what counts as a useful resource (or a threat), depending on their bodily structure, needs, and where and how they are situated. Among humans, worldly engagements take on an especially sophisticated form; agents pursue goals, execute coordinated movement sequences, and display selective attunement to their surroundings. Over the course of continuous engagement with their environment, they begin to exhibit recurring patterns of bodily expressivity and response (Di Paolo et al. 2017).

Although a focus on computations and information processing has become central to much contemporary research in philosophy of mind and cognitive science, Egbert and Barandiaran (2014) turn our attention to the way in which the mind is "made out of *habits*, and by *habit*" (2). Continuous interaction with the environment allows for the formation of autonomous sensorimotor structures that allow agents to navigate their world and act intelligently. As more and more sets of coordinated movement patterns develop and become part of an agent's repertoire, habits begin to overlap and become integrated, so that they mutually stabilize and form a bundle. Habit bundles that an agent reliably enacts to perform various tasks include customary ways of moving, speaking, handling artifacts, and interacting with others. Some habit bundles are enacted explicitly and repeatedly, for the sake of achieving various goals, and then refined via practice and feedback. Everyday examples of highly coordinated, skillful activity include dancing, playing a sport, and using tools and technology. These habitual modes of engagement are self-sustaining, yet also *precarious*. Repeated enactments of a movement sequence reinforce a particular configuration of brain and bodily dynamics: "the more frequently a pattern of behavior… is performed, the more likely it will be repeated in the future" (Egbert and Barandiaran 2014, 3). Conversely, the muscular dispositions and neural connectivity patterns that support habits bundles destabilize if not exercised frequently enough.

In addition to habitual movement patterns, human agents develop coordinated patterns of attention. Just as sensorimotor patterns are reinforced through repetition, what subjects focus on is modulated by what they have paid attention to in the past. Habits of mind encompass schemas for interacting with and interpreting one's surroundings, and include, for example, a tendency to notice some considerations while ignoring others. These habits arise in conjunction with habitual movement patterns, via the development and self-maintenance of neurobiological configurations and built-up patterns of bodily attunement. Some habit bundles usually are followed temporally by others, other sets can be enacted in parallel, and some interfere with or are in tension with one another. The exercise of one set of habits reinforces or inhibits other patterns of behavior and attention, and this interdependence makes them richer in potentiality. Habits also undergird an agent's enduring concerns and reflect *what they care about*. For example, if an agent has developed habits of wearing makeup, reading beauty magazines, and monitoring their weight, this indicates that they care about their physical appearance.

The notion of habit serves as a possible bridge between an enactivist conception of biological autonomy and discussions of autonomous agency found in moral philosophy. First, living organisms are autonomous in a basic biological sense: they regulate their coupling with their environment according to norms of adaptivity, to ensure their continued existence and well-being (Di Paolo 2005, 443). Second, at a higher level of organization, *sensorimotor autonomy* involves the formation of dynamic neurobiological and sensorimotor patterns. These dynamically configured stable patterns simultaneously allow for both stability and control, as well as flexibility and *reasons-responsiveness*. On the one hand, habits constitute built-up patterns of engagement that are readily available for use. Because they integrate past experiences, they give agents the skillful know-how to carry out a wide range of tasks. On the other hand, the flexibility of habit allows agents to adjust their behavior in response to changing circumstances. Rather than being a mere triggered response to stimuli, action is *guided* and *selectively targeted*. Thus, adaptive habits are *metastable* and involve a kind of "plastic equilibrium" (Barandiaran & Di Paolo 2014, 5) that prevents them from operating as "unchangeable automatisms" (Di Paolo et al. 2017, 102).

For human agents, adaptive self-regulation goes beyond mere survival and biological self-maintenance and involves *adapting* and *faring well* in a specific sociocultural context. Enactivists rightly emphasize that habit formation is socially embedded and guided by shared normative practices. Just as biological processes of self-maintenance depend on energetic resources, the formation and maintenance of habits depends on social resources. As children engage with specific aspects of their sociocultural environment, their performance is subject to normative assessment as better or worse, and as more or less correct, given situational demands and sociocultural norms. As a child attempts to name various colors, for example, she receives feedback and thereby acquires a "feel" for which uses are acceptable. As she plays with toys, she learns what sort of play, with which sorts of toys, is appropriate in her specific society.

Shared cultural practices continue to shape meaning-making throughout adulthood, by "prescribing and normalizing certain modes of experience and action while proscribing (and perhaps pathologizing) certain others" (Kirmayer and Ramstead 2017). Rather than relying on explicit rules to tell them what to do, agents adapt continuously to the people around them and let situational and contextual demands constrain their behavior. Along these lines, Haslanger (2019) maintains that "those who have internalized the cultural techne of their context develop dispositions to participate in the practices fluently and to correct those who don't" (19). Dominant practices encompass a set of prevailing attitudes and beliefs that function as tools for social regulation. Related social norms and expectations modulate how agents behave at parties, how they speak to their colleagues, and even how they walk down the street. As agents learn how to use tools and other resources, neurobiological configurations and behavioral patterns form and take root. This allows them to display a rich and recognizable array of mental states that are "suitably tailored to the kind of agency [they] are expected or permitted to develop in [their] given cultural milieu" (McGeer 2019, 52).

The notion of habit helps to make sense of the way in which sociocultural influences are internalized and anchored in patterns of engagement, so that agents' living bodies become "socially saturated." Insofar as these influences mold agents' habits of behavior and attention and coordinate their shared activity with others, they become part of their lives in a quite literal sense, by modifying their neurobiological dynamics and patterns of bodily attunement. Human agents are thereby *mindshaped:* their sense-making processes and embodied habits are *partially determined*, or *shaped*, by the social world.

How does this occur? Enactivists emphasize that bodily coordination is central to human sociality. De Jaegher and Di Paolo (2007) characterize "coordination" as the non-accidental correlation between two or more coupled systems, so that their behavior matches to a degree far beyond what is expected given what those systems can do. Once two or more interactors are part of a coupled system, their expressions, behaviors, and bodily dynamics modulate those of the other person(s); their habits and expressions begin to resonate. Instances of mutual coordination include synchronization, mirroring, and anticipation. This reciprocal bodily attunement begins in infancy and grows more complex over time as agents develop a range of projects that require them to communicate and cooperate with others. Because humans are essentially social creatures who yearn for acceptance and connection, it's inevitable that social norms and cultural expectations will have a significant impact on their ongoing habit formation.

14.4 An Enactivist Account of Adaptive Preferences

Mindshaping often is constructive and enabling insofar as it helps individuals to develop the habits and skills associated with various socially defined activities. Because they can reliably expect that others will respond to, complement, or complete their own actions in particular ways, agents can engage in various forms of joint activity. Social settings such as families and workplaces, for example, offer forms of social coordination that agents are highly motivated to engage in and which prove to be highly valuable (Haslanger 2019, 6). The fact that agents are mindshaped by various socio-normative practices enables them to be part of a community and develop various skills. Thus, the notion of mindshaping helps to make sense of autonomy's integral relational dimension: we are not self-made, self-sufficient beings who exist separately from others, nor should we aspire to such independence (See Urdangarin & Umerez, this volume). Social relations frequently provide crucial scaffolding for autonomous agency. Acknowledging the potential benefits of mindshaping helps us to conceptualize, in enactive terms, the sense in which AP's are *adaptive*. At a basic biological level, adaptivity concerns survival and self-maintenance. But at a higher level of organization, adaptivity is defined partly in relation to normative constraints that are underdetermined by biology, and which derive from the sociocultural environment (See Virenque, this volume). People comply with dominant practices because there is a sense in which it contributes to their human flourishing, as members of a culture. Some modes of engagement are adaptive insofar as they enable the individual to gain status and social recognition, and some are maladaptive insofar as they involve heavy penalties or social disapproval. Thus, one central reason why AP's are "adaptive" is that they allow an agent to behave in ways that others understand, approve of, and find meaningful.

However, habits formed in the context of oppressive social practices also can cause significant harm. In cases of destructive mindshaping, harmful social influences modulate cognition, affectivity, and agency in ways that run counter to a person's broader interests. Once associated habits become internalized and anchored in the body, they may go unquestioned. Consider, for example, how "women are induced to wear high heels by a system that defines high heels as attractive and that prompts women themselves to find these shoes attractive" (Walsh 2015, 834). AP's then can be understood as habit bundles that encompass customary behavioral patterns and a particular orientation toward the surrounding world. The habits that comprise harmful APs form largely due to overdetermining social influences, ones which (a) necessarily operate covertly, and (b) significantly undermine plasticity and flexible agency.

First, social influences are over-determining in the sense that they operate covertly, without the agent being self-reflectively aware of their impact. Following Colburn (2011), I understand covert social influences to be ones whose impact on an agent's behavior or attention is *necessarily hidden* from her. That is, the social influence must remain hidden, outside of an agent's conscious awareness, for it to exert its effect. If someone is brainwashed into following the rules of a cult, for example, there is something about which they cannot know that explains their behavior. It is precisely because this agent remains unaware of the impact of these social influences, and unable to critique them, that resulting habits have such as strong grip on their behavior. In cases of AP, the "brainwashing" typically is subtler; the agent may be vaguely aware that their preferences have been molded by social forces yet remain unaware of the extent to which associated habits have been shaped by dominant norms. This lack of insight increases their tendency to comply with, or even become invested in, oppressive practices.

However, since agents often are unaware of the full extent to which they have been molded by social forces, covert influence is not yet sufficient. In addition, to qualify as overdetermining, social influences must contribute to the formation of habits that are overly rigid. Such habits undermine autonomous agency insofar as they pose a threat to flexibility: agents may become "stuck" in patterns of behavior and attention and inadequately responsive to relevant considerations and situational contingencies. Rigidly engrained behavior patterns may very well overrule or inhibit other situationally relevant actions; likewise, ossified habits of mind may render subjects oblivious to relevant considerations and closed off to alternative ways of viewing things. For example, suppose that socially-inculcated habits associated with conforming to prevailing beauty norms begin to operate somewhat mechanically, outside of reflective awareness. In such cases, the feedback loops between the individual and the social world are quite lopsided, and there is little in the way of active contribution or experimentation. "Scripts" and their associated habits are enacted unthinkingly, and socialization functions more like indoctrination.

These rigid habits pose a threat to well-being partly because they interfere with the enactment of other habit bundles and goal-oriented pursuits that are important to the agent. Consider, for example, a woman who feels they "must" wear high-heeled shoes, even when this interferes with other important goals and interests (e.g., playing with their toddler). Likewise, someone who "prefers" to comply with dominant beauty practices may devote lots of time, energy, and money to this project, leaving them with less resources to enact more fulfilling habits. And a man who "prefers" to exhibit stoicism and habitually suppresses their emotional experiences may find it difficult to enact habit bundles associated with a caretaking role (e.g., being an attentive father). Furthermore, because the habits of behavior and attention that comprise AP's have become "second nature" and begun to operate as a matter of common sense, agents may enact them even in cases where it is evidently inappropriate or harmful to do so.

However, my proposed account also can acknowledge that even when agents exhibit these localized disruptions to autonomy, their general capacity for autonomous agency remains intact. Embodied-enactive principles emphasize that human agents are not passive subjects; although they are shaped by the social world, they also can influence their social environment via their contributions and responses. As autonomous agents, they have some power to resist dominant social practices and develop counter-cultural habits. And when individuals succeed in altering their habits of behavior and attention, this can have a salient rippling effect on other agents and potentially pave the way for the formation of new cultural practices. Consider how belonging to a feminist consciousness-raising group can strengthen agents' ability to reflect on social norms and develop skills for resisting harmful social practices. Such group activity can be understood as an instance of socially scaffolded engagement that strengthens participants' ability to exercise autonomy. Conversely, when an agent enacts habits associated with oppressive social practices, this increases the likelihood that other people in their social world will behave in similar ways. Thus, the notion of mindshaping helps to conceptualize how oppressed people sometimes perpetuate oppressive practices, by way of compliance with dominant norms.

It's worth noting that some agents enact and maintain the habits associated with AP's more self-reflectively and with a greater degree of autonomy. Indeed, cases in which the agent has scrutinized their preferences but continues to enact associated habits for strategic reasons show that social norms often are not internalized wholesale. Consider, for example, a woman who recognizes that her preference to wear make-up is socially inculcated and problematic in some respects, yet also recognizes that it brings social rewards. Some oppression-complicit behaviors are rational in the sense that they reveal active bargaining with a set of social constraints; given limited options, agents strive to do the best they can to advance their interests, and in some cases, all available options may involve some sort of harm or penalty. Arguably, this agent exercises a greater degree of autonomy than someone who has not even considered the mindshaping impact of dominant social practices.

14.5 Conclusion

Agents who have been molded by oppressive social influences and practices may form adaptive preferences and find it difficult to scrutinize or resist associated habits. These influences are harmful insofar as they operate covertly, undermine plasticity, and potentially contribute to internal instability. As a result, agents sometimes become "stuck" in specific patterns of engagement and their attunement to relevant options and considerations diminishes. The notion of mindshaping helps to conceptualize how dominant social norms are internalized and anchored in the body, in the form of engrained bodily habits. However, the disruptions to autonomous agency associated with AP's occur not because the agent has been influenced by their social surroundings—for this is always the case—but rather because associated behavior patterns interfere with the enactment of other important habits and make it more difficult for them to engage effectively with their surroundings.

In addition, it is important to recognize that members of oppressed social groups are not only victims, but also agents, and that their individual acts of resistance sometimes contribute to a radical modification of the social world. In many cases, this occurs via more constructive mindshaping: working together, agents investigate their habits and endeavor to reshape them. Enactivism thereby lends support to the relational view of autonomy endorsed by many feminist philosophers.

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Index

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X. E. Barandiaran and A. Etxeberria (eds.), *Outonomy*,
SpringerBriefs in Philosophy, https://doi.org/10.1007/978-3-032-05501-9