OUTONOMY
Fleshing out autonomy beyond the individual

Project Description

"Outonomy: fleshing out autonomy beyond the individual" is a research project lead by Leonardo Bich and Xabier E. Barandiaran with Kepa Ruiz-Mirazo, Jon Umerez and Arantza Etxeberria as members of the research team and a network 24 research collaborators including PhD students, postdoc researchers and international researchers. With project ID PID2019-104576GB-I00 Outonomy was awarded by the Spanish Ministry of Science and Innovation for the period 01/06/2020-31/05/2023 within 2019 Call for "R + D + i Projects", as part of the framework of the State Programs for the Generation of Knowledge and Scientific and Technological Strengthening of the R + D + i and R + D + i System Oriented to the Challenges of Society of the National Plan for Scientific and Technical Research and Innovation 2017-2020.

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SUMMARY

Summary of the project

The concept of autonomy, understood as the capacity of a system to set up and follow the norms of its own functioning, is of central relevance to contemporary science and society. Recently, the increasing acknowledgement of the deep interconnectedness, mutual dependence and multiscale embeddedness of several natural and social phenomena, has directly challenged the very idea of autonomy, together with those of individuality and identity, and the possibility of its applications to scientific and social challenges. Building on top of 25 years of philosophical and transdisciplinary research at the IAS-Research Center for Life, Mind and Society, centered on a naturalized theory of autonomy in biological and cognitive sciences, this project aims to expand theories of autonomy autonomy beyond classical conceptions of the individual by including integrative, relational, collective and environmental dimensions into it. To do so the project pursues 4 main goals: 1. To develop a notion of integration that is capable of delivering operational criteria to understand how diverse types of autonomous organizations are kept together cohesively, to address controversial cases such as symbiotic systems, human microbiome, mother and foetus relationship in pregnancy, and to deliver socially relevant outcomes for the understanding of biological and psychological personal identity. 2. To explain how higher levels of autonomy emerge from the interaction between autonomous systems and how these new levels in turn limit or expand the autonomy of their constituents: from dyadic relationships to collective agency, from autonomous social habits to the constitution of democracies. 3. To enlarge the concept of autonomy to include relevant aspects of the environment it relies upon, particularly when this environment is transformed by the recurrent action of the subject and creates additional structures that may constitute material or epistemic scaffolds, challenges and threats to the viability of biological systems. Analogous challenges in the domain of human autonomy are found in our technological environment, including increasingly autonomous artificial intelligence, and the way it can jeopardize or enhance personal and democratic self-governance. 4. The last goal concerns the development of a concept of autonomy that includes issues of sustainability beyond the scale of an individual organization: ranging from holobionts, oecological associations, requirements for open-ended evolution, to the governance of social-ecological network in the context of contemporary climate crisis. In order to achieve these transdisciplinary goals the methodology involves naturalist conceptual analysis and synthesis based on an active dialogue with empirical research, computational and mathematical models and scientific theories. The profiles of the 5 research team members in philosophy of science, philosophy of biology and complex systems is complemented by a work team of 24 collaborators including social scientist, computer modellers, network and data analysts, biologists and environmental scientists. High impact is expected in the fields of philosophy (general), philosophy of biological and envi-

ronmental sciences and philosophy of social sciences as a result of 12 Q1 papers in specialized philosophy and scientific journals, one monograph, a review paper in a general Q1 philosophy journal and at least 12 communications in conferences.

Keywords

Autonomy, philosophy of science, philosophy of biology, social theory, complex systems, democracy, collective agency, ecology, integration, symbiosis

Summary of expected impact

The main philosophical, scientific and technical impact of the project is the improvement of our understanding of autonomy beyond the limitations of current individual-centered approaches, providing a reconceptualization that is scientifically sound, operationally applicable, tested against different philosophical and social challenges and practically useful in the biological, social and environmental sciences. In particular the impact addresses the following contributions to contemporary scientific debates. 1. The project will overcome current limitations on our understanding of autonomy and individuality within the boundaries of an organism by developing an account of functional integration that can: a) be applied to different case studies (from the emergence of life to the neural dynamics), b) be used to address highly controversial cases like the status of collective symbiotic systems, of the human microbiome, of the relationship between mother and foetus in pregnancy, c) be combined with a theory of control and regulatory processes. In turn, this is expected to help understand current dilemmas on the understanding of contemporary personal biological and psychological identity. 2. The project outcomes will also impact on current debates regarding the emergence of different levels of collective and social autonomy, and to fill some missing gaps for a multiscale theory of autonomy covering: a) organism-organism dyadic interactions in biology, b) the emergence of collective forms of autonomous agency, c) the social constitution of individual autonomy through social habits and d) the emergence of political autonomy in democratic societies. 3. Conceptual contributions of the project will also impact on current views in epistemology and the philosophy of natural and social sciences by reconsidering the neglected role of the environment in the generation and transformation of autonomous systems: a) with an updated notion of extended autonomy that can contribute to contemporary debates on the role the environment as a scaffold on the origins and evolution of life, b) it will impact on the way the technological environment is conceived on contemporary theories of networked democracy and social autonomy in digital media, and c) on the understanding of the epistemic role of artificially autonomous (or partially autonomous) systems in the

study and transformation of natural ones, and, finally, d) on contemporary debates around the necessary regulation of Artificial Intelligence and synthetic biology to preserve human and social autonomy. 4. Finally, we expect impact on contemporary philosophy of biology by integrating large scale issues of sustainability in the theory of biological autonomy (something that has not been done before) and into the understanding of normative requirement for life that go beyond the scale of the individual. We end up contributing to the emerging field of social-ecological networks in environmental science with a theory of social- ecological autonomy. Technical impact is expected at the level of methodological analysis and modelling of autonomous systems within network-theoretical approaches, multi-agent systems and mathematical measurements of integration.

1. BACKGROUND AND STATE OF THE ART.

1.1. Motivation and Relevance.

The concept of autonomy, understood as the capacity of an entity to set up and follow the norms of its own functioning (to govern itself), is of central relevance to contemporary science and society. In biological and ecological sciences, it is crucial for an understanding of the distinctive character of living systems, of how they maintain themselves as cohesive units in a changing environment. Philosophically, it provides the tools to distinguish actions apart from mere events, life as intrinsically distinct from inanimate matter, or social dynamics as creative and endowed with self-governing capacities. In moral and political terms, it is a fundamental analytical and regulatory concept strongly linked with values of freedom and democracy.

Recent advances in both biological and social sciences have brought to the surface the limits of concepts such as individuality and identity, and the need to provide a better understanding of the complexity of biological and social phenomena by including their interactive and relational dimension at the core of our conceptualizations. The increasing acknowledgement of the deep interconnectedness, mutual dependence and multiscale embeddedness of natural and social phenomena, that make systems' boundaries blurry and difficult to identify, forces us to revisit classical distinctions and categorizations. It challenges us to update and expand our models, to improve methods and change classical assumptions. In this scenario, important contemporary scientific and social issues have directly challenged the very idea of autonomy and the possibility of its application in these domains, and they have even led to suggest that the notions of individuality, identity or autonomy are rendered useless or inadequate: (a) from the discovery of the complex, often highly heterogeneous, biological associations that put into question the notions of organism and individuality (Gilbert et al., 2012); to the critique to the notion of identity in sociology (Brubaker & Cooper, 2000); (b) from the difficulties to identify the very boundaries of the agent in cognitive science (Clark, 2007) to the challenge of setting up genuinely collective forms of autonomous agency (Carter et al. 2018); (c) from the acknowledgement of the crucial role of (and the threats posed by) natural and artificial scaffolds for the viability and development of autonomous systems (Caporael et al., 2013) to the pressing need to develop tools to understand sustainability and self-governance in biological and social organisations (Ostrom, 2009).

The challenges emerging from the study of interactive phenomena call for an update of the classical conception of autonomy, characterized by an inward perspective, and pose two fundamental questions: What if a better understanding of the "autos", the self, requires crossing the traditional boundaries of the individual? How would that alter our very understanding of autonomy? Our research team has been elaborating a concept of autonomy in biological, cognitive and social sciences for the last 30 years, and has

received international acknowledgement for its contributions to philosophy and for its theoretical work within sciences. The notion of autonomy, as articulated by numerous contributions of the research team (Barandiaran & Ruiz-Mirazo, 2008; Moreno, Etxeberria, & Umerez, 2008; Moreno & Mossio, 2015) – and understood as the organizational principle by which a system produces and maintains itself and generates the norms according to which it acts and operates – could accommodate some of these challenges, but to fully benefit from these advances, further work is needed to develop all of its conceptual scope and explanatory potential.

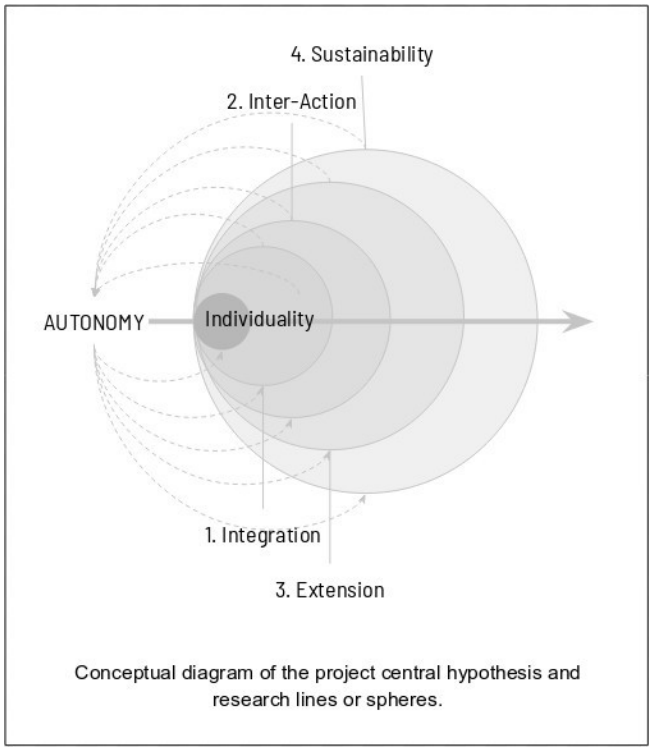
The project "Fleshing out autonomy beyond the individual" (OUTONOMY) aims to update this philosophical and theoretical framework to respond to these new challenges, by fleshing out the concept of autonomy beyond traditional inward perspectives on individual autonomy in order to face current scientific and social challenges.

1.2. Working hypothesis and previous contributions of the research team

The central hypothesis is that **understanding autonomy in the context of contemporary scientific problems and social challenges requires to include integrative, relational, collective and environmental processes that go beyond the individual and yet directly affect and constitute the self-governing capacities it can display**. In particular, we argue that this development of the autonomy framework needs to take place by addressing four fundamental issues. They belong to four dimensions of increasing scope, which proceed from the integrated organization of autonomous systems to their sustainability in the environment, and cut across a variety of biological, ecological and social phenomena:

1. The issue of **integration** in autonomous systems, as an organizational principle to understand how 'physiological' cohesiveness emerges within and across systems.
2. The issue of how **inter-actions** between autonomous systems can give rise to supra-individual or collective forms of autonomy and how these can alter the autonomy of the former.
3. The issue of the **extension** of autonomous systems into their environment (from prebiotic scaffolds to technology) to achieve viability and coordinate regulatory self-governing processes.
4. The issue of **sustainability** (at different scales) of new eco and socio-ecological systems emerging from previously independent autonomous systems.

These issues will be addressed by four research lines. Each issue (integration, inter-action, extension and sustainability) will be addressed starting from case studies and applications from biology, given the high level of expertise of the research and work teams is in this domain. Coherently with the transdisciplinary nature of the project, common questions, models, and answers to the main questions results will be also elaborated, and applied to the study of other phenomena from the ecological and social domains.



Conceptual diagram of the project central hypothesis and research lines or spheres.

In the last 5 years,'IAS-Research' members have been exploring several inter-active aspects of the idea of identity (i.e., the way in which identities are built, modified and sustained through interactions), providing new insights into the most important problems related to that concept in distinct fields (biological, cognitive, social, ethical). The current proposal has been conceived in continuity with that previous work, directed by different PIs, initiated in 2014 with the MINECO funded project "inter-identities" (or 'identity-in-interaction' FFI2014-52173-P). The solid conceptual framework developed as a result of the long tradition of research on autonomy implemented by IAS-research over the years, together with the possibility to rely on the recent work carried out on the different dimension of inter-identities, explored in diverse empirical contexts, is an excellent platform to tackle this new project, since it allows pursuing more in depth the cohesive set of closely interrelated epistemic objectives that underlie the different research lines.

1.2.1. RESEARCH LINE 1 - INTEGRATION

The first research line, focused on integration, will be developed in the context of the contemporary debate on individuality. The notion of individual as an integrated entity within clear-cut boundaries, that can therefore be clearly distinguished from its environment, has been challenged by many advances in natural and social sciences. The biological notion of individuali-

ty has been historically tied to organisms (Etxeberria and Umerez, 2016). Despite the abundance of different accounts and foci, these contributions have been generally thought to be talking about the same units. Likewise, the notion of autonomy has been developed and applied in this context having organisms as the main explanandum, and concepts such as boundaries and closure as explanans (Moreno and Mossio, 2015). Yet both the notion of organisms and individual, as well as the strategies for their identification, have been put into question by studies of highly integrated collective or composite entities arising out of interactions – from biofilms and holobionts (multicellular hosts with all their associated microbes) to pregnancy, from colonies to social insects – that transcend traditional organisms but exhibit some of the features usually ascribed to individuals (Gilbert, et al. 2012; Skillings 2016). Recent research on host-microbiota and, more generally, symbiotic relationships characterized by close functional ties, questions the possibility to establish clear functional boundaries for biological systems. Two alternative, yet unsatisfying, solutions have been suggested to confront the problem of individuality: a) a wide generalization across evolution, physiology, metabolism, immunology, and ecology, with very few arguments on why and how these multidimensional criteria should go together (Pradeu, 2016) and, b) a fragmented descriptive approach where the notion of individuality have become merely descriptive of the scientific practice; with a different notion of individuality being indexed to the objects of study in each field: anatomical individual, immunological individual, physiological individual, ecological individual (Kovaka, 2015). Cognitive and social sciences have witnessed parallel problems. On the one hand the subject-environment distinction has been called into question (Clark, 2007), spreading cognition across brain, body and environment. On the social side, the notion of collective identity has been strongly criticized and calls to its abandonment have been made (Brubaker & Cooper, 2000).

The need for a thorough and precise investigation based on conceptual or theoretical criteria is therefore especially pressing given these new understandings of a wide range of cohesive associations of natural and social entities. A good theoretical account should be able to provide criteria or strategies to trace the functional boundaries of a system in different cases, but it might be particularly difficult to do so while avoiding the opposite extremes of essentialism and vagueness, if we consider the multifarious interactions with the environment that a system needs to undergo and maintain in order to exist.

In this scenario, the main aim of this research line is to provide an understanding of autonomy and individuality in terms of functional integration (G1.1) within and between autonomous systems, rather than in terms of boundaries and closure alone, and more specifically: how different subsystems come together into cohesive systems at different levels (G1.2), and how the behavior of components is controlled and coordinated in such a way that they can contribute to the maintenance of the system (G1.3). Whereas the concept of (functional) integration has often been considered cru-

cial to tackle the issue of individuality (Godfrey-Smith, 2013), i.e. the idea that an individual is an integrated whole whose functions are strongly interconnected, a precise and detailed account of integration has not been provided in biology yet, thus leaving unanswered this fundamental question. The lack of such an account and the unclear character of this notion as used in the current literature, undermines not only current definitions of individuality in general, but also the debate focused specifically on the controversial cases mentioned above. Parallel to this problem in the philosophy of biology, the notion of integration, including explicit mathematical formulations and empirical measurements, has been intensively applied to address the problem of the unity of consciousness in brain dynamics (Tononi et al. 2016). A proper philosophical evaluation of how this method can be used to update the concept of autonomy and solve some of the problems of biology is still and open task.

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Adequacy of research team: In the context of the origins of life, previous work has been done to understand the functional requirements of prebiotic autonomous systems (Ruiz-Mirazo and Moreno, 2006). The organizational requirements for cellular autonomy (Moreno and Mossio, 2015), multicellular autonomy (Arnellos et al, 2013, Bich et al, 2019) and biological control and regulation (Bich et al., 2016) have been investigated. In addition, preparatory work is under development on collective control and the boundaries of biological symbiotic associations (Bich, 2019; Militello et al., under revision), and on the biology of pregnancy as an interactive phenomenon, a preliminary step to address the significance of pregnancy for the debate on individuality (Nuño de la Rosa et al., in preparation). The notion of integration has been suggested as a criterion for individuation by some members of the group (Barandiaran 2004) and recently applied to robotic agents (Aguilera, Alquézar & Bedia, 2018).

1.2.2. RESEARCH LINE 2 – INTER-ACTION

While the first research line tries to understand how an autonomous organisation is kept together in a cohesive unit, this second line focuses on the agential capacity of such organisations: how they interact with each other and how relational and higher levels of autonomy might emerge out of these interactions.

Many interactive phenomena between two or more autonomous systems at different scales, from the biological to the social, modulate the constitutive organisations of the interactors. They therefore constitute challenges for our understanding of autonomy. In biology, these phenomena span from quorum sensing in bacteria, to signaling and communication between different species such as in the case of the human microbiome (Keely, 2017), to superorganisms (Arnellos et al. 2019). Similarly, in psychological and social sciences, the traditional and individualistic (liberal and Kantian) conception of autonomy has repeatedly being challenged by structuralist, post-mo-

dern and feminist philosophers (Mackenzie & Stoljar, 2000) and by psychotherapy (Harris, 2011). The resulting challenge is that of updating our notion of autonomy including symbiotic, dyadic and long term stable interactions that increase the interdependence between autonomous systems while enhancing their autonomy beyond what they could individually achieve (G2.1).

One way to move beyond classical conceptions of the individual is to depart from the notion of social habit or habitus (as developed by Dewey or Bourdieu) as building blocks for the social constitution autonomy. The very notion of habit has also been revised and lately fostered to be essential to understand cognitive autonomy and as a form of behavioural autonomy in itself (Egbert and Barandiaran, 2014), but a thorough synthesis between the concepts of (personal or agential) autonomy and social habits is still missing (G2.2).

Another contemporary challenge is represented by the phenomenon of collective autonomous agency: how is it possible for a collective of autonomous individuals to give rise to a higher order agent, and how does this new level of autonomy limit or enhance the autonomy and agential capacities of its component individuals? Current debates regarding collective agency have mostly developed under intellectualist and rationalist assumptions (List & Pettit, 2011) and only recently have emergentist and embodied approaches contributed significantly to this open debate (Carter et al., 2018; Satne, 2019). The notions of biological and sensorimotor autonomy have much to contribute to this debate and the link has seldom been made yet (G2.3).

Scaling up from the domain of the collective to that of the political, the way in which social identities constitute and govern themselves in a continuous and open interaction with other social structures, institutions and antagonistic identities, forces us to rethink autonomy as emerging from multitudinous and magmatic social strata rather than from the rational aggregation of individuals (Castoriadis, 1991). The concept of social autonomy can be further enriched by conceptual, methodological and modelling contributions coming out of research in biological and behavioural autonomy (G2.4).

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Adequacy of research team: The research team can tackle these challenges and make sense of these phenomena by relying on and developing previous work on minimal and multicellular autonomous agency (Barandiaran et al., 2009; Arnellos and Moreno, 2015), on an organizational approach to biological communication (Frick et al., 2019), on superorganisms (Arnellos et al., 2019) and some preliminary explorations have been made on the social nature of habits (Bedia et al., 2019). Also, preliminary progress on making use of biological and complex systems approaches to identity have been made to develop the notion of social and multitudinous identities

(Monterde et al., 2015) and understanding social organization (Siqueiros & Umerez, 2005).

1.2.3. RESEARCH LINE 3 - EXTENSION

The third research line addresses the challenges to the notion of autonomy posited by the recurrent interactions with and interventions on the environment, which can also, in turn, become "artificially autonomous". The underlying idea is that all autonomous systems rely on environmental scaffolds for their maintenance, and that an analysis of specific roles played by environmental factors for different types of autonomous systems need to be developed without reducing the role of the environment to mere background.

In the context of philosophy of biology two questions regarding the environment are particularly relevant, for what concerns the way in which relations of organisms with the biotic and abiotic environment may be constitutive of their autonomy (G3.1). In the context of the origins of life, the question of the importance of environmental scaffolds has been traditionally posed in terms of the relative complexity of the emergent protocellular or proto-metabolic systems with regard to the complexity of the environment (i.e., the 'prebiotic soup' in which life is supposed to have thrived, Ralser, 2018). At the moment one of the main debates in the field of origins of life is between alternative models for the appearance of the first metabolic pathways (Muchowska et al., 2019): whether these initial pathways were autotrophic and required little complexity in the environment, or heterotrophic in which case a large pool of organic compounds must be made available to them, as a scaffolding for their evolutionary development.

Other crucial biological phenomena in which the environment plays a direct role are extended heredity and reproduction, in which some environmental factors and other organisms act as scaffolding for the realization of these processes, which are not autonomous in the sense of independent, but require the collaboration with environmental biotic and abiotic factors (Griesemer, 2014; Minelli, 2016).

Social sciences constitute a privileged field for the analysis of the role and challenges provided by artificial environments to autonomous systems (G3.2). Human and social forms of autonomy are particularly prone not only to the extension into self-modified environments (dwellings, cities, etc.), but also to the production of technological devices and infrastructures that become progressively more constitutive of our personal and collective autonomy (Clark, 2007) at all levels, including the political one, such as in the case of digital networked infrastructures involved in Artificial Democratic Life (Barandiaran, 2019).

Artificial extension into the environment does not only concern personal and social interactions but is also involved in the generation of scientific knowledge. A challenge faced by scientific and philosophical thought

concerns the role of specific disciplines, such as Artificial Intelligence, Artificial Life and Synthetic Biology, which produce (an alternative version of) their object of study, not only for technological applications but also to contribute to a better understanding of natural and human phenomena (G3.3). The debate on the practices and the distinctive methodology that characterize Synthetic Biology, to consider just one of these disciplines, is very rich (O'Malley, 2009, Damiano and Cañamero, 2012). Yet, a thorough analysis of the overall role of this discipline, and of its artifacts, in domains such as origins of life is still missing. This project will explore the scientific claims of these disciplines and more specifically the epistemic role of artificial autonomous systems (synthetic systems, robots, etc.) to study and modify natural ones in domains such as origins of life, minimal agential and cognitive systems, etc. In parallel, it will address the issue of how artificial autonomous systems might hinder the autonomy of human systems as in the case of Artificial Intelligence in the context of the platform society (Van Dijk, Poell & De Waal, 2018) and its continuous intervention in personal and social (democratic) forms of autonomy (G3.4).

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Adequacy of research team: the group can count on a long tradition of work on several aspects or implications of Artificial Intelligence, Artificial Life and synthetic biology by many members of the group (Barandiaran & Moreno 2006, Moreno et al, 2008; Ruiz-Mirazo and Moreno, 2013; Bich and Green, 2018). Regarding the issue of technological environments for social autonomy and the threads of artificial intelligence for democracy, Xabier Barandiaran has been director of Research, Development and Innovation in Participatory Democracy at Barcelona City Council during the 2016-2018 period and has published several reports and scientific papers (including collaborations with other members of the work team such as A. Calleja-López and A. Monterde) on these matters, as well as various radio and television appearances regarding philosophical reflection on the effect of Robotics, Artificial Intelligence and digital infrastructures in society and democracy.

1.2.4. RESEARCH LINE 4 - SUSTAINABILITY

The fourth and last research line is focused on the problem of the long-term sustainability of autonomous systems, with a particular attention on collective phenomena. Sustainability is currently a hot topic in scientific and political debates. It cuts across several disciplines in natural and social sciences, and involves theoretical, ethical and political aspects. This scenario, therefore, is particularly suitable for a philosophical and interdisciplinary research aimed at providing conceptual tools to understand and discuss the viability of different forms of autonomous organization together with collective social practices.

While in the past the concept of autonomy has been mainly elaborated in terms of ongoing processes (under the expression "current organization"), the aim of this research line is to explore more in depth a different

temporal dimension: the long term one which is critical to understand the current presence and the conditions for future existence of autonomous systems.

This research line will be developed in close relation to the previous ones, and will benefit from the results and conceptual tools derived from them. The first challenge it will address (G4.1) is the problem of ecological sustainability requirements of new forms of integrated organization emerging out of interaction: symbiotic relationships, holobionts and, more, generally those collective systems that exhibit new interacting capabilities not present in the starting entities. Two important dimensions of the problem need to be considered in this respect. The first is the nature of the new ecological relationship between associations of autonomous systems and their environments: more specifically, the new ways in which these entities gather resources and affect their ecological conditions of existence; a context of increase of relational complexity and expanding utilization of ecological spaces (Knoll and Bambach, 2000). The second is the stability of functions of higher level ecological self-maintaining regimes characterized by production and exchanges or resources, despite changes in the types of systems that realize them (Doolittle and Booth, 2017). While this topic is relatively new for the autonomy framework, it can rely on previous foundational work on ecological functions (Nunes-Neto et al., 2014).

The second challenge concerns the evolutionary sustainability of collections of autonomous organisations beyond their intrinsic robustness (G4.2). Addressing it requires taking into account the role of reproduction, development and life cycles (Griesemer, 2016). The autonomy framework developed by the research team has emphasized the importance of open-ended evolution to understand the biological autonomous systems (Ruiz-Mirazo et al., 2008; Etxeberria, 2015). Yet, this account has been criticized during the last decade for not providing a compelling account of trans-generational functions such as reproduction (Artiga and Martinez, 2017). This debate triggered several responses by members of the research team, aimed at solving the conceptual issue of reproduction (Mossio and Pontarotti, 2019, Moreno, 2019). This work has opened the way for a more detailed analysis of the conditions for open-ended evolution and long term evolutionary sustainability of autonomous systems: how autonomous system can undergo an indefinite number of transformations and re-definitions in the context of a wider and temporally more extended population.

The third challenge concerns the social domain, and more specifically those practices that involve collective action aimed at achieving and improving sustainability (G4.3).These practices encompass initiatives for the maintenance and management of common pool resources and collective actions in urban and natural areas. From the philosophical and political points of view they are deeply embedded in the debate on common good and self-management (Menatti, 2017). Recent progress in sustainability science has put the emphasis on collaborative governance in social-ecological networks in relation to environmental sustainability (Ostrom, 2009). Although the

term “autonomy” is rarely used in this debate, and references to the biological conception of autonomy are scarce, there is a deep connection between research in the philosophy of biological autonomy, sustainability sciences and the idea of self-governing social-ecological networks, that can be fruitful to develop to face contemporary challenges in climate change and sustainable forms of life. Moreover, the notion of social metabolism (Sayles et al., 2019), might provide a bridge between biological and environmental philosophy that the theory of autonomy still has to explore.

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Adequacy of research team: The research and work teams can rely on the foundational work cited above on ecological functions, open ended evolution and biological reproduction from the point of view of autonomy, in addition to a general work on robustness of biological and complex systems across levels of organization (Bich, 2018). Together, they constitute the conceptual starting point to address environmental sustainability from the biological and ecological points of view. Regarding the socio ecological domain, although this is an almost new topic for the team, the project can count on an extensive preliminary work on common good and social practices (Menatti, 2017) and on the normativity of socio-ecological systems (Nunes-Neto et al., 2016) and on social metabolism (Sayles et al., 2019), in addition to the expertise of IP1 on participatory democracy.

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NOTE: publications preceeded by * are authored by members of the research team and work group

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2. GENERAL AND SPECIFIC GOALS AND RELATED RESEARCHERS

2.1. Goals

G0: GENERAL GOAL: To expand the notion of autonomy beyond the individual, encompassing the integration of organizational, (inter)active-collective, external-artificial and large-scale sustainability dimensions.

The main goal will be divided into specific goals and subgoals listed below:

G1: Integration. To develop a notion of integration that is capable of delivering operational criteria to understand how diverse types of autonomous organization are kept together and how the activities of their components are cohesively coordinated.

- **G1.1** To develop a general account of functional integration for autonomous systems that can be applied to different cases from the emergence of minimal autonomous protocells to embodied neurodynamics in humans.
- **G1.2** To reformulate (on the basis of a more precise notion of functional integration) the philosophical notion of individuality to account for the challenging cases of individuals arising out of interactions, such as: collective symbiotic systems, the eukaryotic cell, the relationship between mother and foetus in pregnancy.
- **G1.3** To develop an account of the main control and regulatory mechanisms that contribute to the coordination of the different subsystems of an autonomous system (i.e. metabolic control, immune control, spatial control; internal communication mechanisms, etc.).
- **G1.4*** To analyse the limits of traditional biological, psychological and social categorizations, such as genetic individuality and identity, and clarify the main issues brought forward in the public debate in controversial areas of special interest for society such as medicine, psychiatry and specific cases like human microbiome.

G2: Inter-action: To develop a notion of autonomy that is applicable across scales of interactive organization from the individual to the collective and back.

- **G2.1** To develop a framework to study the role of organism-organism relations (physiological and communicative) for the constitution of biological autonomy at different scales and for evolution.
- **G2.2** To elaborate an account of collective agency as resulting from the autonomous interactions between individuals.
- **G2.3** To develop a model of social habit that brings together the autonomy of individual behaviour and its collective shaping.

- **G2.4*** To explore the connection between operational definitions of autonomy, as tend to be applied to natural systems, and the concept of autonomy related to social and multitudinous identities in democratic networks.

G3: Extension: To enlarge the concept of autonomy so that it includes the very environment it relies upon, particularly when this environment is transformed by the recurrent action of the subject by creating additional structures, new conditions, challenges and threats in the external media.

- **G3.1** To elaborate a critical and synthetic revision of the role assigned to the environment in the philosophy of biology literature, with a special focus on the role of environmental scaffolds in the generation and transformation of autonomous systems.
- **G3.2** To develop a notion of social autonomy and democracy that includes digital networked infrastructures and digital media as constitutive of social autonomy and to specify the design principles for digital platform development capable to enhance this form of autonomy.
- **G3.3** To clarify the epistemic role of artificially autonomous (or partially autonomous) systems in the study and transformation of natural ones (e.g. synthetic biology, artificial intelligence).
- **G3.4*** To investigate the potential and threat of Artificial Intelligence and synthetic biology to the autonomy of individuals and collectives in contemporary societies.

G4: Sustainability: To include in the framework of autonomy aspects that concern the longer-term sustainability of a collection of individuals: i.e., aspects that usually lie outside the spatiotemporal scale of the ongoing operations of an autonomous system but they are critical to understand its current existence and the future existence of similar systems.

- **G4.1** To analyze the requirements for the interactive sustainability of new forms of organization emerging from interactions (holobionts, symbiosis, syntrophic ecological associations, etc.).
- **G4.2** To elaborate a theoretical framework to understand the long-term maintenance of autonomous systems based not only on their robustness as complex individuals but, more critically, on functions, such as their capacity for reproduction, that transcend the internal organization of the system, with potential for open-ended evolution.
- **G4.3*** To develop a concept of autonomy that encompasses collective actions, collaborative self-governance and practices for sustainability within social-ecological networks.

2.2. Goal leaders and research and work team members

- G1. IP responsible: Leonardo Bich

- G1.1 Responsible: Kepa Ruiz-Mirazo. Members of research team: Leonardo Bich, Xabier Barandiaran, Arantza Etxeberria. Members of work team: Alvaro Moreno, Guglielmo Militello, Dora Tang (Biology), Miguel Aguilera (Computer Science), Nino Lauber (Computer Science and Biology).
- G1.2 Responsible: Leonardo Bich. Members of research team: Arantza Etxeberria, Jon Umerez. Members of work team: Alvaro Moreno, Guglielmo Militello, Miguel Escribano, Alejandra Martinez, Derek Skillings (Philosophy and Biology), Alba Amilburu.
- G1.3 Responsible: Leonardo Bich. Members of research team: Jon Umerez, Kepa Ruiz-Mirazo. Members of work team: Alvaro Moreno, William Bechtel, Matteo Mossio, Alejandra Martinez, Nino Lauber (Computer Science and Biology), Dora Tang (Biology), Matthew Egbert (Computer Science).
- G1.4 Responsible: Leonardo Bich. Members of research team: Xabier Barandiaran, Arantza Etxeberria. Members of work team: Derek Skillings (Philosophy and Biology), Miguel Aguilera (Computer Science), Maria Ferrera Ruiz.

- G2. IP Responsible: Xabier Barandiaran.
  - G2.1 Responsible: Arantza Etxeberria. Members of research team: Leonardo Bich Members of work team: Matteo Mossio, Laura Nuño de la Rosa, Derek Skillings (Philosophy and Biology).
  - G2.2 Responsible: Xabier Barandiaran Members of work team: Enara Garcia (Psychology), Glenda Satne.
  - G2.3 Responsible: Xabier Barandiaran. Members of work team: Miguel Aguilera (Computer Science), Matthew Egbert(Computer Science), Arnau Monterde (Communication Science).
  - G2.4 Responsible: Jon Umerez Members of research team: Xabier Barandiaran. Members of work team: Antonio Calleja-Lopez (Sociology), Miguel Aguilera (Computer Science), Luce Prignano (Complex systems).
- G3. IP Responsible: Xabier Barandiaran
  - G3.1 Responsible: Arantza Etxeberria. Members of research team: Kepa Ruiz-Mirazo, Leonardo Bich. Members of work team: Laura Menatti, Miguel Escribano, Laura Nuño de la Rosa, Maria Ferreira Ruiz.
  - G3.2 Responsible: Xabier Barandiaran. Members of work team: Antonio Calleja-Lopez (Sociology), Arnau Monterde (Communication Science), Luce Prignano (Complex systems).
  - G3.3. Responsible: Leonardo Bich. Members of research team: Jon Umerez, Kepa Ruiz-Mirazo, Arantza Etxeberria. Members of work team: Luisa Damiano

    - G3.4 Responsible: Xabier Barandiaran. Members of work team: Miguel Aguilera(Computer Science), Josè Luis Aznarte (Artificial Intelligence), Antonio Calleja-Lopez (Sociology), Luce Prignano (Complex systems).
- G4 IP Responsible: Leonardo Bich
    - G4.1 Responsible: Leonardo Bich Members of research team: Kepa Ruiz-Mirazo Members of work team: Gugliemo Militello, Derek Skillings (Philosophy and Biology), Alejandra Martinez.
    - G4.2 Responsible: Kepa Ruiz-Mirazo. Members of research team: Arantza Etxeberria. Members of work team: Laura Nuño de la Rosa, Matteo Mossio, Miguel Escribano.
    - G4.3. Responsible: Jon Umerez. Members of research team: Xabier Barandiaran. Members of work team: Laura Menatti, Violeta Cabello (Environmental Science), Maria Mancilla Garcia (Environmental Science).

3. METHODOLOGY & WORKING PLAN

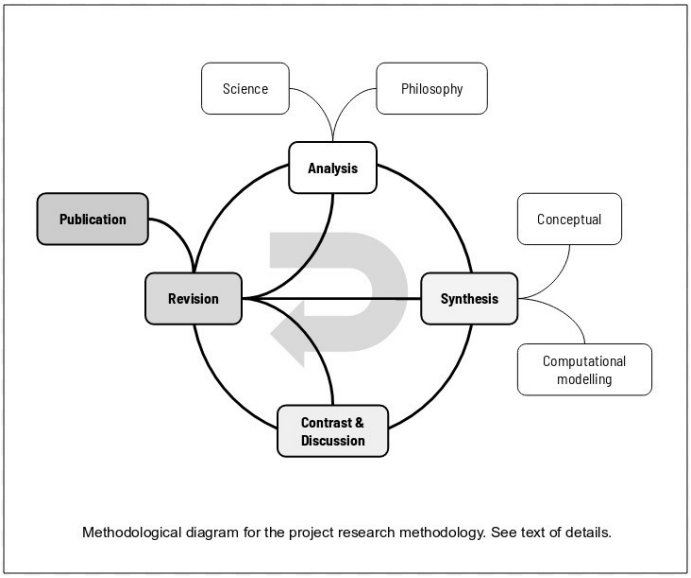
3.1. Methodology

The main philosophical methodology of the project involves naturalist conceptual analysis and synthesis based on an active dialogue with empirical research, computational and mathematical models and theoretical concepts as well as discussion and confrontation with alternative theories. In particular this methodological approach involves the following steps:

- Conceptual analysis as a result of
  - Literature review for the philosophical or more theoretical aspects of the problem involved: (i). Mapping of the main positions or distinctions in the theoretical debate, and (ii). Identification of specific problems or tension within or between approaches.
  - Literature review for the relevant empirical and, in general, scientific case studies and contributions that can shed light on the theoretical problem(s) under investigation.
- Conceptual synthesis of new categories or philosophical and theoretical accounts that are needed to address the problem.
  - This conceptual synthesis is sometimes expressed in terms of minimal models or minimal theoretical and philosophical accounts build upon basic case studies.
  - The development of conceptual simulations or computational models (mostly using network science tools, agent-based modelling, numerical calculus for differential equation modelling and optimization methods, like genetic algorithms, for parametric fitting and multivariable regression methods for pattern identification).
  - Adjustment of the model to the empirical literature to evaluate the plausibility and relevance of the synthesis.
- Contrast and discussion at different scales:
  - With scientists to establish a constant feedback between philosophical and scientific research, and to pursue active collaborations on common issues.
  - With other philosophers and theoreticians, searching both collaboration and constructive discussion between opposing approaches.
  - In wider academic conferences and symposia, with reviewers, etc.

- Revision of the conceptual synthesis or problem definition in the light of discussion or new empirical findings or challenges.
- Publication of final results.

Apart from the naturalist philosophical research method explained above, some of the research goals will include a fruitful intersection between the philosophy of natural sciences (the stronger expertise and research background of the group) and the philosophy of social sciences. This trans-disciplinary crossover with philosophical and theoretical methodologies can be named biological grounding, embeddedness and analogy. By biological grounding we mean the research into the biological foundations of social phenomena and its critiques, specifying or questioning assumptions regarding the biological limits, determinants, possibilities and potentialities. By biological embeddedness we refer to the research on the way in which social phenomena occur (also) in a natural environment (including human bodies or ecosystems). Finally, conceptual and methodological analogies between natural and social sciences make possible to extend models and methods from the realm of biology, neural or physical sciences to the domain of the social, where it is generally harder for scientists to carry out controlled, detailed and complex experiments. The notion of autonomy is particularly suited to this transdisciplinary methodology, because the philosophical problems of freedom, determinism and self-governance not only expand from the physical to the psycho-social, cutting across the neuro-biological, but also suffer from a traditional methodological split between intellectualist traditions that ground autonomy on rational and self-reflective capacities and the natural sciences.



Methodological diagram for the project research methodology. See text of details.

Trans and inter-disciplinary collaborative methodologies will be used for crew meetings, seminars and workshops, including design-thinking methodologies, collaborative writing techniques. These methodologies will also include participation and discussion protocols aimed at neutralizing the gender domination structures that are usually imposed in scientific and academic meetings.

3.2. Working plan

The research methodology will not be carried out individually but in different levels of cooperation between research-team and work-team members of the project. In general, each goal will be pursued by at least one interdisciplinary research-crew made of, at least, one senior or postdoctoral philosophy researcher, a junior or predoctoral philosophy researcher, supported when needed by a scientist or modeller. These crews constitute the nodes of a collaboration network. Crews will host regular meetings to share knowledge, references, analysis and to make progress on the synthetic proposal. Every two months a session of the IAS-Research seminars (a regular series of research seminars that have been taking place for the last 8 years) will be devoted to the OUTONOMY project (overall 3 seminars per research line during the duration of the project). In general, seminars will involve external-open sessions and an internal-closed sessions. Internal sessions will be used to contrast and call for feedback on the analytic or synthetic achievements or work in progress on the goals, whereas external sessions will involve inviting external collaborators to expand on their areas of expertise in order to provide valuable input for the goals. They will also serve to attract wider audiences and to carry out dissemination activity.

Every two months there will be a coordination meeting between the two IPs and the postdoc (when hired) in order to review the state of the project. Every six months there will be a meeting of the research-team to keep track of the progress in each goal. Meetings with the whole network of collaborators (the work-team) will take place 5 times during the project duration: 1. Kickoff meeting, 2. Internal project workshop, 3. Public external workshop, 4. Progress report meeting and 5. Evaluation meeting. The internal workshop will make the outcomes of the first part of the project available to be discussed and reviewed by the rest of project members. During this gathering, drafts of research outcomes (goal specification, progress report, working hypothesis, achieved and expected publications) will be discussed and evaluated collectively between research and work team members.

A public workshop will take place in November 2021. For this event the research results are expected to be mature and open to revision within a wider community of contributors and experts. This workshop will be the most important mid-project milestone of the project, bringing together key invited speakers for each research line and presentation of results for each subgoal (by members of the project). Speakers of the workshop will be expected to contribute an extended abstract to be peer reviewed. A selection of the contributors to the workshop will be invited to submit a paper to the monograph. Monograph contributions are expected to be submitted 3-6 months after the workshop and to include the feedback from the workshop discussions. Peer reviewed revised versions of the monograph are expected

to be published 4 months before the end of the project. Publication of the monograph will be followed by a communication campaign to ensure proper dissemination of the project results.

Parallel to the research process culminating in the Workshop and the Monograph, research crews for each sub-goal (except Goals G1.4, G2.4, G3.4) are expected to deliver a research article in a specialized Q1 journal (total 12) and to present their work in at least one international conference. The G.1.4, G2.4, G3.4 will deliver a paper in Q2 journals (tot. 3). The overall approach is that this parallel research outcome is to be published and contrasted among a more specialized audience (e.g. a philosophy of biology journal or an origins of life journal) whereas the contribution to the monograph makes an effort to achieve a wider level of generality or philosophical abstraction. This way interdisciplinary naturalism can contribute both to general philosophical problems and feed back to specific sciences and disciplines.

The project includes the organization of two additional workshops, with a more specific target. One such workshop will focus on a specific research line, to be resolved as the first stages of literature review and analysis deliver specific needs, challenges and results to be addressed and discussed in this workshop. The second workshop has a prespecified focus. Some of the objectives of the project address autonomy in relation to problems of sex, gender, and reproduction. We propose to carry out a workshop entitled Forgotten Female Bodies II in 2021 (the first edition was held in 2018), to give particular emphasis to these aspects of the project. We expect researchers of the team to participate and to invite eminent speakers to discuss issues such as the relational explanations of biological reproduction; maternal-filial relationship in pregnancy; the evolution and biological organization of the menstrual cycle in humans and; more generally, feminist interpretations of individuation and autonomy.

Finally, the project includes an effort to synthesize all the results. With this goal in mind, the project includes the submission of a review article synthesizing the project results and providing a new and extended notion of emergent autonomy to a Q1 philosophy journal. Depending on the nature of the results this article may be a position paper co-authored by multiple members of the group or an elaboration of the IPs .

The Gantt chart below depicts the temporal unfolding of the work plan as exposed in section 1.4. Important project events and activities, expected submission deadlines and research activities are shown on the diagram. Each goal follows the methodological steps defined above (sec. 1.4.A), the milestones and events described in detail in section 1.4.C. Research activities and submission data have been allocated to balance research-crew workload and theoretical interdependencies. Dissemination publication of social impact research goals have been distributed to match evenly distributed impact and input from relevant research goals.

We now provide a list of goal IDs (see section 1.3 for a full detail of project goals) followed by the researcher that is responsible for the goal (as coordinator) and subgoals (as research leader), followed by research team members and work team members. Special attention has been put to complete interdisciplinary research-crews for each subgoal according to methodological requirements. Scientific and computational analysis and modelling expertise is shown next to researcher name in the case of crew members who are not philosophers.