

Introduction

Scientific frameworks in biology, ecology, medicine, and related fields increasingly study organisms as systems shaped by continual interactions with their environments. Yet, the very notion of ‘environment’ remains conceptually opaque, even as it has become a distinct philosophical object of inquiry rather than merely the counterpart to living beings. Recent collected volumes and special issues have taken up this challenge by revisiting, historicizing, and re-conceptualizing the environment in the life sciences and medicine (Pontarotti *et al.*, 2022; Baedke & Buklijas, 2023; Casetta, 2024). Together, these efforts reflect a broader narrative shift within the sciences and across broader knowledge domains, away from paradigms grounded in individualism, struggle, and separation. In their place, emerging explanations emphasize interdependence and the dynamic role of the environment in both evolution and our understanding of life itself. From this perspective, the environment is no longer a static external backdrop but an active participant in evolutionary and developmental processes, one that is continually transformed by the activities of organisms.

This reflects a growing recognition of the environment's complex and multifaceted significance in philosophical inquiry, particularly within the philosophy of biology and medicine as well as environmental philosophy. The many meanings of ‘environment’ reveal a complex conceptual landscape where the term defies simple definition. Its ubiquity is matched by its complexity, characterized by polysemy, pluralism, and its fundamentally relational qualities. Despite being dictionary synonyms for environment, terms like *milieu*, *Umwelt*, and *ambiente* or *medioambiente* carry distinct historical and conceptual nuances, each encoding different understandings of spatial, biological, and perceptual relationships.

As Gagliasso (2019) also argues, the traditional separation between organisms and environments is no longer adequate, because contemporary biology and ecology show them to be deeply interdependent. Life not only adapts to environments but actively produces, modifies, and degrades them, creating dynamic feedback loops that shape evolution and planetary conditions (Merlo & Barandiaran, 2024). In fact, how we frame the environment fundamentally shapes how people understand environmental problems and how they respond to them (Lakoff, 2010). Rather than referring to a single, stable concept, ‘environment’ encompasses a heterogeneous set of meanings that embody distinct philosophical commitments concerning its relation to living systems. This re-conceptualization also highlights long-standing asymmetries in how organisms and environments have been understood, while contemporary research programs, such as epigenetics, exposomics, and holobiont biology, push toward frameworks of symmetry, mutual shaping, and co-constitution. A similar shift appears in Caianiello *et al.* (2023), who show that in contemporary organoid and organ-on-chip research the ‘microenvironment’ is no longer treated as a passive setting but as an active, causally efficacious system whose biochemical,

mechanical, and spatial features co-determine cellular behavior, development, and pathology.

With the aim of addressing the conceptualization of the environment itself, this paper considers how the organism/environment relation implies that living systems are inseparable from the conditions they inhabit while taking into account that those conditions are not external but produced by them in interdependence. In fact, current organismal perspectives understand organisms and environments in terms of pairings and the reciprocal influences each exerts on the other (Casetta, 2025; Baedke *et al.*, 2021; Fabregas-Tejeda, 2026; Etxeberria, 2026). It will also examine how relations of organisms with other organisms can be integrated within an environmental approach, emphasizing that biotic interactions are fundamental components of the environment and play a crucial role in shaping ecological and evolutionary dynamics. In relation to this, it is particularly pertinent to highlight how living organisms and species alter the environments of other entities, giving rise to entangled surroundings, including anthropogenic effects. Building on this contrast, the notion of *interdependent surroundings* is proposed to argue that organisms continually transform not only their own but also each other’s conditions of existence.

1. *The notion of environment*

There are very different kinds of narratives and conceptual traditions attempting to make sense of the notion of the environment in science, medicine and philosophy. A very influential one was Canguilhem's account of the history of the notion of *milieu* in his article ‘Le vivant et son milieu’, first published in 1952 and later, included in *La connaissance de la vie* (Canguilhem, 2008). His essay examined how the relational character of the milieu concept evolves in scientific thought among different insights appearing in biology, medicine and ecology. Canguilhem portrays the organism as a relational being, one in which «the relationship between the organism and the environment is the same as that between the parts and the whole of an organism» (Canguilhem, 2008, p. 111). The organism-environment relation as forming a system has been expanded and reassessed in numerous studies recently (Pearce, 2010, 2014; Etxeberria, 2020; Fabregas-Tejeda, 2026).

Canguilhem locates the notion of milieu in Newtonian mechanics, where it originally referred to a fluid medium (ether) that mediated between bodies and transmitted causal action. In biology, Lamarck used ‘milieux’ (in plural) for elements like air or water surrounding organisms, alongside ‘influencing circumstances’ to describe environmental effects – terms that later informed Darwin’s ‘conditions of existence’ even though Darwin never used the word *environment*. It was Herbert Spencer who introduced that term in the late 19th century (Pearce, 2010), coinciding with the emergence of a more abstract, singular conception of environment. Around this time, the more abstract conception of the environment in the singular also emerged. Canguilhem highlights how the modern understanding of environment was shaped by a sequence of key thinkers: Auguste Comte’s unification of physical surroundings and influential cir-

cumstances; Alexander von Humboldt's early vision of a global, ecological environment; Bernard's articulation of the *milieu intérieur*; and Jakob von Uexküll's notion of *Umwelt*, which redefined environment as a species-specific, meaningful world constructed through its own perceptual and biological capacities and needs (Wolfe, 2026).

A second and distinct narrative, independent of the historical lineage of *milieu*, draws on environmental historians' accounts of the much more recent emergence of 'the environment' as a new category across the sciences and the humanities. After World War II, and especially with the rise of Earth Systems Science, the environment came to be conceived as a planetary, interconnected entity, a system of physical, chemical, biological, and social interrelations. Warde *et al.* (2018) show how 'the environment' crystallized as a global concept in this period, underpinning the formation of new interdisciplinary fields oriented around the idea of a global environment. This perspective highlights how environmental awareness has contributed to contemporary understandings of the environment as both a scientific and a social construct (Kabasenche *et al.*, 2012). In doing so, it replaces older views of 'nature' as static and intrinsic with a conception of the environment as fundamentally relational and dynamic.

A third perspective emphasizes that the *environment* requires an inherently plural concept, shaped by multiple histories, roles, and intellectual traditions (Benson, 2020; Casetta, 2024; Fabregas-Tejeda, 2026). The notion cannot be reduced to a single meaning. This plurality appears in several dimensions: in the diverse cultural and historical understandings of human–environment relations; in the many roles environments occupy, as resource, habitat, threat, or partner; and in the different disciplinary approaches to environmental questions, ranging from indigenous knowledge systems to contemporary scientific frameworks. Rather than seeking a unified definition, these perspectives highlight that the strength of environmental thought lies precisely in its multiplicity. Environments may be understood at once as physical spaces, webs of relationships, cultural constructs, and fields of action. This pluralism challenges any effort to reduce environmental thinking into a single narrative or conceptual framework.

In short, the environment can be understood as a particular *milieu* (a biological relation), as a global system, or as a plural and situated construct. These multiple senses are crucial for rethinking how forms of life negotiate their emergence within the very conditions that co-produce them.

In the sections that follow, several aspects of the organism–environment relation in biology and medicine are examined to argue that there are advantages in thinking of surroundings as interdependent and plural. While the notion of 'the environment' is useful particularly at planetary level and discussions of practical action, explaining the ontology of life and living systems is better served by attending to plural surroundings. The discussion first addresses the environment as the immediate surroundings of an organism and subsequently turns to the notion of organisms as fundamentally entangled, a perspective that underscores the importance of their connections with other organisms. While

the preceding overview highlighted distinct historical and conceptual accounts of the environment, the analysis that follows will draw primarily on the first of these and consider how the environment is conceptualized within the philosophy of biology.

2. *The environment as surroundings*

For accounts exploring the organism-environment relations the environment appears as the set of conditions that surround the organism, that is, as an external domain of conditions of life, forces and constraints within which life unfolds. Most of those approaches view organism-environment relations in a unidirectional and asymmetrical way, portraying the organism as shaped by an external environment to which it must simply accommodate or adapt, or alternatively emphasizing how organic processes construct independent organizations to avoid environmental variation. In contrast, the reciprocal process whereby organisms actively construct and modify their environments remains comparatively under-theorized; a reciprocal dynamics requires understanding organisms as active agents in evolutionary and developmental processes, capable of modulating their own internal conditions through self-organizing dynamics, mobilizing plastic responses to environmental variation, and also altering the environments they inhabit.

This means that agential actions aimed at modifying the organism-environment relation, whether to adapt better or to respond to challenging situations, can entail changes to the agents themselves (for example via plasticity) or of the environment (construction). In this sense, both faces of niche construction are at play: on the one hand, the capacity to physically alter surrounding conditions, and on the other, the strategies organisms use to reshape how those surroundings are perceived or experienced, a dimension captured by the notion of *experiential niche construction* (Chiu, 2019; Haukedal, 2025). These environmental modifications entail both deliberate as well as unintended consequences, such as wastes, residues, and metabolic byproducts, that reshape selective pressures and contribute to the historical layering through which living systems evolve (Boudia *et al.*, 2021).

2.1. *Tilting toward one pole*

As suggested elsewhere, historically, the relation between organism and environment has often been represented through asymmetries: either the organism dominates its environment or the environment determines the organism (Etxeberria, 2026). We may distinguish two main forms of asymmetry. An *internalist* one where the organism is conceived as a self-organizing and self-regulating system that maintains its identity against environmental perturbations. From Kant to Claude Bernard and Walter Cannon, life has been defined by its capacity to preserve internal stability regardless of external changes. This paradigm was consolidated in the twentieth century through cybernetics and Maturana and Varela's theory of autopoiesis, which viewed living systems as

organizationally closed (Maturana & Varela, 1980). The environment, in these models, tends to appear as a source of disturbances that the system compensates for internally. This internalist view accentuates the centrality of internal regulatory processes and pays less attention to how they depend on the environment. Recent proposals reconceive autonomy not as independence from the world, but as an *open and relational process* – one that depends on constant exchange with the surroundings (Barandiaran & Etxeberria, 2026).

A second major asymmetry is *externalist* and appears in evolutionary biology, particularly in the Modern Synthesis, where the environment is defined as an external selective force shaping the adaptation of organisms. In this view, the environment acts, and the organism responds. Philosophers such as Robert Brandon described several notions of environment, external, ecological, and selective, but all of them maintained the same one-way causality: the environment affects organisms but is not affected by them (Brandon, 1990). This model was challenged by authors such as Richard Lewontin, Richard Levins, and Denis Walsh, who emphasized reciprocal causation: organisms not only adapt but also modify their environments (Levins & Lewontin, 1985; Walsh, 2015). Theories such as niche construction and enactivism show that evolution is a dynamic dialogue between organisms and their surroundings.

Thus, internalist and externalist views differ in portraying the environment as either a passive background or an external determinant. Overcoming this opposition requires understanding life as co-constituted by organisms and their environments.

2.2 *The organism-environment system*

To move beyond one-sided views, we must treat organism and environment as a single system, as noted in the earlier sentence from Canguilhem. The recognition that organisms do not stand apart from their environments becomes particularly evident in three contemporary fields: epigenetics, exposomics, and holobiosis.

Epigenetics has transformed modern biology by showing that environmental factors directly influence gene expression without altering DNA sequences (Buklijas, 2018; Nicoglou & Merlin, 2017). From Waddington's early concept of the 'epigenetic landscape' to today's molecular studies on DNA methylation and non-coding RNA, biology has revealed that organisms are deeply shaped by their interactions with the environment. This new view undermines the traditional gene-centered hierarchy and replaces it with networks of interdependence, or 'heterarchies', where control is distributed (Bich & Bechtel, 2026). Environmental signals become integrated into the organism's molecular constitution, blurring the line between internal and external. This shift calls for rethinking autonomy as a relational process in which organism and environment co-emerge through interaction. Drawing on Karen Barad's agential realism (Barad, 2007), learning, plasticity, and metabolism appear as co-constitutive processes rather than mere adaptations.

The second area, exposomics, examines the full range of environmental exposures, chemical, biological, social, that affect an organism throughout its life. The exposome, defined as everything non-genetic within the body, reveals that living systems are porous and permeable, constantly exchanging matter and information with their surroundings. This approach challenges the classical image of the body as a closed entity. Researchers such as Hannah Landecker (2017, 2024) and Nancy Krieger (2005) have shown how social conditions, stress, and inequality are biologically embodied: the body literally *records* its exposures. Bodies are relational interfaces that both shape and are shaped by their environments. Moreover, the exposomic perspective exposes the ethical and political dimensions of biology: environmental effects are unevenly distributed, reflecting social hierarchies and injustices.

The third domain, holobiosis, further dissolves any residual boundary between organism and environment by showing that what we call an 'organism' may be, in fact, a consortium of species living in continuous metabolic and developmental integration. Modern biology radicalizes this insight through the concept of holobiont, developed by Lynn Margulis (Margulis, 1990; Margulis & Sagan, 1997). A holobiont is a symbiotic consortium, a host and its associated microbes, that functions as an integrated unit. From this viewpoint, individual organisms are composite and collective entities, defined by their interactions; it reveals that physiological functions such as digestion, immunity, development, and even behavior depend on microbial partners that are neither strictly internal nor external (Gilbert *et al.*, 2012). Studies on microbial inheritance, for example, show that what is transmitted across generations is not only genetic material but also ecological relationships: the reproductive success of many organisms hinges on acquiring specific microbial communities from their habitats. Holobiosis reveals that living systems maintain coherence while drawing on, and contributing to, a shared ecological milieu (Etxeberria *et al.*, 2023). It thus exemplifies the central claim of this section: organism and environment are components of one evolving system, co-produced across developmental, ecological, and evolutionary timescales.

3. From entangled organisms to interdependent environments

With Darwin, a decisive relational turn begins: the focus shifts considerably from the environment as what surrounds the organisms to the web of relations among organisms and living beings as they take place in those surroundings. This dimension of organism-environment balance was stressed by Canguilhem, who notes that for Darwin the most fundamental biological relations are not with the physical milieu but with other organisms, such as parasites, predators, preys, allies or competitors (Canguilhem, 2008). Interdependencies of this kind, especially those displayed in symbiotic associations and captured by the notion of holobiont, show that relations among organisms are key to understanding the relational nature of life and must be considered alongside organism-environment relations.

This is illustrated with cases such as mammalian pregnancy, in which gestator and embryo engage in immunological and metabolic exchanges, or early caregiving relationships, which shape development through attachment and stress regulation (Nuño de la Rosa *et al.*, 2021). These examples show that biological individuality is relationally constituted. Organisms are never fully autonomous but are enmeshed in complex ecological and social webs. Holobiosis captures this shift: life is not an isolated property of individuals but a process of cooperation and interdependence. In the context of the Anthropocene, where human-made mass already exceeds the planet's biomass (Elhacham *et al.*, 2020), this view becomes even more urgent. Life involves both composition and decomposition, creation and decay; the environment is not external to organisms but entangled with them in cycles of transformation.

Ecological entanglement does not end with the organism; it radiates outward into the very fabric of its surroundings. Through countless interactions, cooperative, competitive, or indifferent, species alter the material and energetic conditions of the places they inhabit. Environments, in this sense, are the evolving expressions of these entangled lives.

Recent developments in biology and philosophy of life mark a shift from viewing the environment as an external backdrop to understanding it as a dynamic entanglement of organisms and relations. Symbiosis, microbiomes, niche construction, and ecological network theory all reveal that organisms not only inhabit environments but actively participate in their ongoing formation. Environments, in this view, are not pre-given settings but historically and materially constituted through reciprocal processes of interaction, modification, and co-dependence. Insights from systems biology, ecology, and relational ontologies in the philosophy of biology converge on this perspective, proposing extended and distributed conceptions of the organism that blur the boundaries between life and *milieu*. The environment thus emerges as a living nexus of relations.

The evidence from epigenetics, exposomics, and holobiosis confirms that biological individuality is porous, dynamic, and interconnected.

The concept of *interdependent surroundings* offers a philosophical alternative to conventional notions of environment. Rather than conceiving the world as a passive backdrop to life, it understands surroundings as dynamically shaped by the actions, presences, and traces of other organisms. This represents a shift in how we conceive of environmentality: life does not occur within a stable container but within a mutable field co-constituted by countless other organisms. Each act of living reshapes the very atmosphere of existence. This alternative redefines the environment as a living network of mutual influences, where the space around any organism is continually transformed by the actions of others.

4. *Implications of Anthropogenic Evolution*

The notion of *interdependent surroundings* entails that the milieu of living entities is continually modified by other past or present living organisms. Human activity has emerged as one of the most powerful evolutionary forces shaping the environments of life on Earth, a process often termed *anthropogenic evolution*. This

concept encompasses the ways in which organisms and ecosystems adapt to the rapid and pervasive changes in the environment brought about by human influence.

Anthropogenic evolution is understood in different ways depending on the evolutionary approach applied. Within the standard evolutionary framework associated with the Modern Synthesis (MS), anthropogenic change is understood primarily as the introduction of novel selective pressures resulting from human activities. From this perspective, factors such as pollution, habitat fragmentation, urbanization, and climate change modify environments in ways that ultimately alter allele frequencies within populations, thereby shaping evolutionary trajectories in response to transformed ecological conditions. Anthropogenic changes also reshape the ecological contexts in which sexual selection operates (Boughman *et al.*, 2024). Because sexual traits such as coloration, calls, and courtship displays are often condition-dependent and highly plastic, they are especially vulnerable to disturbance. Human-induced alterations can disrupt signal-receiver dynamics by modifying trait expression or impairing the ability to assess mate quality; pollutants such as endocrine-disrupting chemicals may alter sexual traits or reduce mate discrimination, while noise can mask acoustic or visual signals. As a result, sexual selection may weaken or shift in both strength and direction, potentially disrupting reproductive isolation mechanisms and eroding the role of sexual selection as a driver of speciation.

By contrast, the evo-devo (evolutionary developmental biology) perspective shifts attention toward the developmental and regulatory mechanisms that generate phenotypic variation. From this viewpoint, anthropogenic influences, such as endocrine disruptors or biotechnological interventions, can reshape developmental pathways, modulate or constrain phenotypic plasticity, and thereby affect an organism's evolutionary potential in ways that extend beyond strictly gene-centered models (Campbell, Bean, Parsons, 2017; Campbell *et al.*, 2021).

In addition, the niche construction framework views organisms, including humans, as active participants in shaping their own environments. Here, anthropogenic evolution is seen as a feedback process in which human-altered settings (urban spaces and infrastructures, agricultural systems, industrial ecologies) recursively influence the evolutionary trajectories of multiple species.

Taken together, these perspectives illuminate distinct yet complementary dimensions of anthropogenic evolution: natural selection, developmental plasticity, and environmental modification.

4.1. *Modified selective pressures*

In general terms, several authors explain anthropogenic evolution by focusing on how rapid human-induced environmental changes alter evolutionary selective pressures (Dugatkin 2024, Baltazar-Soares *et al.*, 2021). This aligns with the standard Darwinian view of evolution, in which environmental conditions ex-

ert selective forces that drive populations to alter their genetic makeup over time in order to adapt.

As Baltazar-Soares *et al.* (2021) describe it, Human-Induced Evolution (HIE) refers to evolutionary changes in heritable traits, or in their genetic and epigenetic bases, that arise from direct or indirect human pressures. A key feature of HIE is its extraordinary rapidity compared with the tempo at which evolutionary processes unfolded prior to the Anthropocene. It acts as a distinct and dominant evolutionary force that unfolds at a much faster pace than natural evolutionary processes, and can produce maladaptive outcomes in natural populations. Historically, HIE was driven by processes such as the domestication of plants and animals, whereas contemporary forms are closely linked to modern socioeconomic development, such as climate change, pollution, harvesting practices (such as hunting and fishing), species translocations and hybridization, and the effects of fossil fuel combustion. These authors underscore the urgent need to understand these processes in order to develop effective conservation strategies and to anticipate long-term evolutionary trajectories under accelerating anthropogenic influence.

For Dugatkin (2024), evolutionary biology is no longer confined to the study of slow, ancient processes; it must now also confront the rapid, human-mediated changes occurring in real time. This form of evolution arises from the environmental alterations caused by humans, and it is already reshaping the behavior, physiology, and survival of countless living species. As he notes, human influence affects where organisms «live, where they breed, what they eat, whom they fight and whom they help» (Dugatkin, 2024).

This author describes several kinds of environmental changes caused by anthropogenic evolution. One involves *mismatches*, which occur when traits that were adaptive in past environments become maladaptive under new, human-made conditions, for example, shifts in breeding seasons or the effects of air and light pollution. Traits shaped by earlier ecological regimes may fail to align with the current conditions, jeopardising reproductive success or survival. Comparable disruptions occur in species exposed to air pollution, which interferes with sensory, respiratory, or signalling systems, and in organisms whose communication or mating signals are distorted by artificial light

A second phenomenon has to do with *ecological traps*, situations in which organisms make poor choices because they rely on cues that now guide them toward suboptimal or dangerous environments. Dugatkin cites the example of hermit crabs being trapped inside discarded tyres (Sogabe & Takatsuji, 2021).

A third set of changes arises from *urbanization*, which creates distinctive and rapidly emerging selective pressures, such as chronic noise, artificial light, altered temperatures, and pollution. These pressures can lead animals to move less than they do in the wild, experience higher ambient temperatures, inhabit brighter spaces, show changes in personality, or acquire novel behaviours that support survival in urban settings.

The Modern Synthesis (MS) approach to anthropogenic evolution focuses on the integration of Mendelian genetics with Darwinian natural selection to

explain evolutionary changes in populations over time. In anthropogenic contexts, MS tends to emphasize how natural selection exerted by human-modified environments affects evolution. Evolution is viewed as a gradual process occurring across generations through mutation, selection, genetic drift, and migration. Within this framework, humans are seen as external selective agents imposing novel pressures on other species, giving rise to phenomena like antibiotic resistance, pesticide resistance, or adaptations in urban pests.

To understand how anthropogenic evolution is framed within the MS, it is essential to recognize that this framework emerged by sidelining ecological and relational perspectives. As Huneman (2025) argues, early 20th-century ecology developed through two organicist models that conceptualized ecosystems as integrated wholes. One of these was a physiological model, treating ecosystems like organisms with interdependent functional parts; the other was evolutionary, grounded in group-level dynamics such as group selection and coadaptation. However, both models were gradually displaced by the rise of the MS, which privileged an individualistic, gene-centered view of evolution. In this framework, evolution is largely understood as the differential survival and reproduction of individuals in response to external selective pressures – ecological systems themselves became mere background, rather than participants in evolutionary processes.

By reducing the environment to an external set of conditions and minimizing interdependence among organisms, the MS makes it difficult to fully comprehend the relational nature of anthropogenic influences: how human activity not only changes individual traits, but also reconfigures the very structure of ecological relationships through which evolution unfolds.

4.2. *Developmental changes*

Anthropogenic evolution can also be understood through its effects on developmental processes and organismal integration. Evolutionary Developmental Biology (evo-devo) research shows how human-induced toxicity can alter or disrupt developmental pathways, and offers a powerful framework for understanding how organisms adapt to anthropogenic environments beyond the gene-centered perspective of the Modern Synthesis. This perspective enriches conservation biology by highlighting the need to protect not only genetic diversity, but also paying attention to the developmental systems that underlie adaptive flexibility in the face of rapid environmental disruption. It focuses on ontogenetic processes and how changes in timing, patterning, growth, and differentiation generate morphological and phenotypic variation and evolutionary novelties (Parsons, 2021). Its units of analysis include regulatory genes, gene expression networks, phenotypic plasticity, and ontogenetic mechanisms. Sanger (2021) gives strong support for arguments that anthropogenic change acts through development, that EDCs and heat produce nonlinear, stage-specific disruptions, and that developmental plasticity and its limits shape species' fates in the Anthropocene. As this work stresses, embryos are especially

vulnerable because of rapid cell division and active signaling pathways, and respond immediately to environmental disturbances, before other effects appear.

Developmental paths altered by anthropogenic changes potentially lead to rapid evolutionary shifts through mechanisms like heterochrony, heterotopy, or genetic co-option. Rather than treating humans as external agents, evo-devo sees them as part of larger ecological and developmental networks that co-shape the evolution of many species, including humans themselves.

A useful illustration of how anthropogenic pressures intersect with developmental processes comes from research on evolvability under climate change. Campbell *et al.* (2021) examined how rising temperatures influence bone development, craniofacial morphology, and performance in *Salvelinus alpinus* (Arctic charr). By rearing fish at 5 °C and 9 °C to simulate projected warming conditions, they documented several temperature-dependent developmental shifts. Individuals raised at the higher temperature exhibited reduced bone and cartilage development, changes in craniofacial shape, including wider jaws at early stages followed by narrower and deeper forms, along with fewer vertebrae, consistent with Jordan's Rule, which predicts increased vertebral counts in colder environments. Elevated temperatures also produced increased local bone metabolism and faster escape responses, indicating performance-related consequences of altered developmental trajectories. Together, these findings show how climate-driven environmental change can reshape developmental pathways in ways that directly modulate an organism's evolvability.

A comparable pattern can be observed in forests, where climate change alters growth dynamics and can constrain the future adaptive capacity of tree populations. Astigarraga *et al.* (2025) show that rising heatwaves, drought, and late spring frosts increase tree growth synchrony, that is, different individuals within a forest begin to grow in more similar ways under climatic stress. As reported in their study of *Fagus sylvatica* stands in Euskal Herria (northern Spain), the frequency of heatwaves and reduced precipitation led to higher synchrony in annual growth rings, particularly in structurally homogeneous stands. In contrast, structurally diverse forests, especially those shaped by traditional management like pollarding, exhibit lower synchrony and more heterogeneous growth responses, which the authors interpret as a sign of greater resilience.

Endocrine-disrupting chemicals (EDCs) also illustrate how anthropogenic factors intervene directly in development by altering endocrine signaling; endocrine systems are central hubs through which organisms sense and adapt to environmental conditions (Seebacher, 2022). These disruptions often interact with other anthropogenic drivers such as heat and artificial light, producing nonlinear and unpredictable developmental effects across generations. Environmental factors modify hormonal pathways that regulate growth, differentiation, and timing, making developmental plasticity a key mediator of organismal responses to change. Because early development sets long-term physiological trajectories, these perturbations can generate transgenerational consequences and reshape ecological and evolutionary outcomes.

In sum, the evo-devo approach foregrounds relationality: it sees humans not simply as agents exerting selection but as participants embedded within broader networks of ecological, developmental, and evolutionary processes. It highlights how reproduction, development, and environment are co-constitutive, generating novel forms and trajectories through their interactions. Thus, Evo-Devo allows for a more integrated and less anthropocentric analysis of evolution in the Anthropocene, emphasizing co-agency and the plastic potential of life under conditions shaped by human practices.

4.3. *Anthropogenic niche construction*

Niche construction is broadly defined as the process by which organisms actively modify their own and each other’s environments, thereby influencing selection pressures, developmental pathways, and ecological interactions (Odling-Smee, Laland & Feldman, 2003). In the context of anthropogenic evolution, this process assumes unprecedented significance. Human-driven niche construction, manifested through urbanization, industrial agriculture, pollution, and climate change, has become a dominant evolutionary force reshaping the biosphere. As a result, species are not only adapting to human-altered ecological niches but are also undergoing developmental and epigenetic reprogramming in response to anthropogenic environments, often in unpredictable or maladaptive ways (Laland *et al.*, 2016). Thus, anthropogenic evolution itself can be understood as a pervasive form of niche construction, one in which human activities systematically transform the selective and developmental landscapes of many species (Dorninger *et al.*, 2023; Marlatt *et al.*, 2022).

Anthropogenic climate change has been conceptualized as a ‘monumental’ instance of niche construction (Meneganzin *et al.*, 2020), one that reconfigures global ecosystems and generates novel selection regimes across taxa. These authors also stress the appearance of *evolutionary traps* in the Anthropocene; the rapid pace of environmental change driven by human activity is outpacing the adaptive capacities of many species, including our own, leading to widespread maladaptation and extinction. They emphasize that human evolution has long been tied to climatic instability, as proposed by the *Variability Selection Hypothesis*, which suggests that environmental unpredictability rather than stable habitats shaped key hominin traits and adaptive flexibility. Climatic fluctuations repeatedly influenced human evolutionary pathways, including major dispersal events such as the successive ‘Out of Africa’ migrations that enabled *Homo sapiens* to become a global species. Yet, they consider that the present situation is unprecedented: our species has become the primary driver of rapid environmental alteration, generating long-term ecological feedbacks that now threaten our own well-being. Meneganzin *et al.* further contend that the cognitive biases and heuristics that evolved under past selective regimes, once adaptive for responding to immediate, local threats, now hinder effective responses to the challenges of climate change. The cumulative effects of human activity have precipitated a biodiversity crisis comparable in scale to past mass extinctions (Ceballos, Ehrlich, Dirzo, 2017). While human evolution has historically

been shaped by climatic variability and environmental instability, the causal relationship has inverted: *Homo sapiens* has emerged as the primary agent producing large-scale environmental transformations.

Ultimately, the feedback between human niche construction and environmental instability exemplifies a central paradox of anthropogenic evolution: the same evolutionary mechanisms that once promoted resilience and innovation now threaten the persistence of complex life systems. Climate change, a historical driver of diversification and adaptation, has become, under anthropogenic pressures, a leading cause of extinction. Anthropogenic effects have been seen as outcomes of long-term entanglements between biological systems and industrial, chemical, and colonial processes. In this sense, Landecker (2024) proposes *anthropogenic biology* to capture how new biological forms arise from long-term entanglements between human practices and living systems, especially those shaped by industrialization.

Conclusions

In the previous section, this paper has argued that organisms (including humans) transform the conditions in which their lives unfold, as well as those of other organisms and has reconsidered the concept of environment. While externalist conceptions frame the environment as a backdrop offering opportunities and constraints, contemporary research across epigenetics, plasticity, symbiosis, microbiomes, ecological networks, and niche construction shows that organisms both inhabit and actively shape the conditions of life. Therefore the notion of ‘environment’ may be reframed as interdependent surroundings in which biological processes occur, surroundings shaped not only by a species’ own activity but also by the actions, infrastructures, and histories of many others.

Recent developments show two main ways of defining the environment. One sees it as an organism’s physical surroundings, and recent work has shifted from viewing these surroundings as strictly external to understanding them as increasingly porous and permeable. The other conceives the environment as a web of relations among organisms, shaped by interactions such as cooperation, competition, symbiosis, and predation. Bringing these perspectives together allows us to see that an organism’s surroundings are influenced both by its own activities and by those of many other organisms. This is why, in addition to recognizing life as entangled, we also need to consider how surroundings themselves are continually modified in interdependent ways.

On this basis, the paper has proposed *interdependent surroundings* as a more adequate notion: organisms modify not only their own circumstances but also those of other species, such that environments emerge from ongoing interspecific interactions. This reconceptualization provides a framework for understanding how species influence one another’s evolutionary trajectories by transforming the relational settings in which development, behavior, and selection unfold.

The relevance of this view becomes clear in the case of anthropogenic evolution, which must be examined through multiple frameworks, in terms of changed selective pressures and, in addition, in how human activities influence the developmental traits of other species and how these alterations trigger niche changes. It is therefore best understood as a paradigmatic case of environmental interdependence, where the surroundings of many species are co-produced through multi-species, material, and historical processes¹.

References

- Astigarraga, J. *et al.* (2025). Forest Structural Diversity Modulates Tree Growth Synchrony in Response to Climate Change. *Forest Ecology and Management*, 579, 122505.
- Barad, K. (2007). *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning*. Duke University Press.
- Baedke, J., Fábregas-Tejeda, A., Prieto, G.I. (2021). Unknotting Reciprocal Causation Between Organism and Environment. *Biology & Philosophy*, 36, 48. <<https://doi.org/10.1007/s10539-021-09815-0>>.
- Baedke, J., Buklijas, T. (2023). Where Organisms Meet the Environment: Introduction to the Special Issue 'What Counts as Environment in Biology and Medicine: Historical, Philosophical and Sociological Perspectives'. *Studies in History and Philosophy of Science*, 99, A4-A9. <<https://doi.org/10.1016/j.shpsa.2022.09.008>>.
- Baltazar-Soares, M., Brans, K.I., Eizaguirre, C. (2021). Human-Induced Evolution: Signatures, Processes and Mechanisms Underneath Anthropogenic Footprints on Natural Systems. *Evolutionary Applications*, 14, 10, 2335-2341.
- Barandiaran, X.E., Etxeberria, A. (2026). Ontonomy, the Very Idea, in X.E. Barandiaran, A. Etxeberria (eds), *Ontonomy: Fleshing out the Concept of Autonomy beyond the Individual*. Springer, 3-12. <https://doi.org/10.1007/978-3-032-05501-9_1>.
- Benson, E.S. (2020). *Surroundings: A History of Environments and Environmentalisms*. University of Chicago Press.
- Bich, L., Bechtel, W. (2026). Autonomy and Heterarchy: Organizing Control in Biological Organisms, in X.E. Barandiaran, A. Etxeberria (eds), *Ontonomy: Fleshing out the Concept of Autonomy beyond the Individual*. Springer, 23-32. <https://doi.org/10.1007/978-3-032-05501-9_1>.
- Boudia, S. *et al.* (2021). *Residues: Thinking through Chemical Environments*. Rutgers University Press.
- Boughman, J.W. *et al.* (2024). Sexual Selection and Speciation in the Anthropocene. *Trends in Ecology & Evolution*, 39, 7, 654-665.
- Brandon, R.N. (1990). *Adaptation and Environment*. Princeton University Press.
- Buklijas, T. (2018). Histories and Meanings of Epigenetics, in M. Meloni, J. Cromby, D. Fitzgerald, S. Lloyd (eds), *The Palgrave Handbook of Biology and Society*. Palgrave Macmillan, 167-187.

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- Caianiello, S., Bertolaso, M., Militello, G. (2023). Thinking in 3 Dimensions: Philosophies of the Microenvironment in Organoids and Organs-on-chip. *History and Philosophy of the Life Sciences*, 45, 14. <<https://doi.org/10.1007/s40656-023-00560-z>>.
- Campbell, C.S. *et al.* (2021). Evolvability under Climate Change: Bone Development and Shape Plasticity are Heritable and Correspond with Performance in Arctic Charr (*Salvelinus alpinus*). *Evolution & Development*, 23, 4, 333-350.
- Campbell, C.S., Bean, C.W., & Parsons, K.J. (2017). Conservation Evo-Devo: Preserving Biodiversity by Understanding its Origins. *Trends in Ecology & Evolution*, 32, 10, 746-759.
- Canguilhem, G. (2008). The Living and its Milieu (1965), in *Knowledge of life*, trans. by S. Geroulanos, T. Meyers. Fordham University Press, 98-120.
- Cannon, W. (1929). Organization for Physiological Homeostasis. *Physiological Reviews*, 9, 3, 399-431.
- Casetta, E. (2023). Has Climate Change Ended Nature?, in T. Andina, F. Corvino (eds), *Climate Change and Global Distributive Justice*. E-International Relations, 83-100.
- Casetta, E. (2024). *Philosophy of the Environment: An introduction*. Routledge.
- Dearden, P.K. (2026). Evo-Devo and the Biodiversity Crisis, in W. Tworzydło, S.M. Bilinski (eds), *Evo-Devo: In Search of New Model Species*. Springer, 37-46. <https://doi.org/10.1007/978-3-032-06766-1_3>.
- Delbes, G. *et al.* (2022). Effects of Endocrine Disrupting Chemicals on Gonad Development: Mechanistic Insights from Fish and Mammals. *Environmental Research*, 204(B), 112040. <<https://doi.org/10.1016/j.envres.2021.112040>>.
- Ceballos, G., Ehrlich, P.R., Dirzo, R. (2017). Biological Annihilation via the Ongoing Sixth Mass Extinction Signaled by Vertebrate Population Losses and Declines. *Proceedings of the National Academy of Sciences*, 114, 30, E6089-E6096.
- Chiu, L. (2019). Decoupling, Commingling, and the Evolutionary Significance of Experiential Niche Construction, in T. Uller, K. Laland (eds), *Evolutionary Causation: Biological and Philosophical Reflections*. MIT Press, 299-322.
- Dorninger, C., Menéndez, L.P., Caniglia, G. (2023). Social-ecological Niche Construction for Sustainability: Understanding Destructive Processes and Exploring Regenerative Potentials. *Philosophical Transactions of the Royal Society B*, 379, 20220431. <<https://doi.org/10.1098/rstb.2022.0431>>.
- Dugatkin, L.A. (2024). Anthropogenic Evolution: Humans are Changing more than just the Environments Species Inhabit. We are Changing the Species Themselves. *Scientific American*, 330, 6, 62.
- Elhacham, E. *et al.* (2020). Global Human-made Mass Exceeds All Living Biomass. *Nature*, 588, 7838, 442-444.
- Etxeberria, A. (2020). Regulation, Milieu, and Norms: Georges Canguilhem's Individual Organisms as Relations, in P. O. Méthot (ed.), *Vital norms. Canguilhem's the Normal and the Pathological in the Twenty-First Century*. Hermann, 291-328.
- Etxeberria, A. (2026). Environment(s), Autonomy and (A)symmetries, in X.E. Barandiaran, A. Etxeberria (eds), *Autonomy: Fleshing out the Concept of Autonomy Beyond the Individual*. Springer, 35-44. <https://doi.org/10.1007/978-3-032-05501-9_4>.
- Etxeberria, A., Cortés-García, D., Torres Aldave, M. (2023). Organisms, Life Relations, and Evolution: Inter-dependencies after Kropotkin's Mutual Aid. *ArtefaC-ToS: Journal of Science and Technology Studies*, 12, 1, pp. 179-204.
- Fábregas-Tejeda, A. (2026). *The Organism-environment Pairing: a Historical and Philosophical Re-appraisal*. MIT Press, forthcoming.

- Gagliasso, E. (2019). Organisms and Environments as Combined Systems. *Academicus – International Scientific Journal*, 10, 20, 119-127.
- Gilbert, S.F. (2024). Inter-kingdom Communication and the Sympoietic Way of Life. *Frontiers in Cell and Developmental Biology*, 12:1427798. <<https://3389/fcell.2024.1427798>>.
- Gilbert, S. F., Sapp, J., Tauber, A. I. (2012). A Symbiotic View of Life: We Have Never Been Individuals. *The Quarterly Review of Biology*, 87, 4, 325-341.
- Haukedal, R.S. (2025). *Agency and Organisation: The Dialectics of Nature and Life*. Springer.
- Huneman, P. (2025). The Chicago School of Ecology's Evolutionary Superorganism and the Clements-Wright Connection. *History and Philosophy of the Life Sciences*, 47, 1, 12.
- Kabasenche, W.P., O'Rourke, M., Slater, M.H. (eds) (2012). *The Environment: Philosophy, Science, and Ethics*. MIT Press.
- Krieger, N. (2005). Embodiment: A Conceptual Glossary for Epidemiology. *Journal of Epidemiology & Community Health*, 59, 5, 350-355.
- Lakoff, G. (2010). Why it Matters How We Frame the Environment. *Environmental Communication*, 4, 1, 70-81. <<https://doi.org/10.1080/17524030903529749>>.
- Laland, K.N., Odling-Smee, F.J., Feldman, M.W. (2003). Niche construction, ecological inheritance, and cycles of contingency, in S. Oyama, P.E. Griffiths, R.D. Gray (eds.), *Cycles of contingency: Developmental systems and evolution*. MIT Press, 117-126.
- Laland, K., Matthews, B., Feldman, M.W. (2016). An Introduction to Niche Construction Theory. *Evolutionary Ecology*, 30, 2, 191-202.
- Landecker, H. (2017). Metabolism, Autonomy, and Individuality, in S. Lidgard, L. Nyhart (eds), *Biological Individuality*. University of Chicago Press, 225-248.
- Landecker, H. (2024). How the social gets under the skin: From the social as signal to society as a metabolic milieu. *Köln Zeitschrift für Soziologie*, 745-767. <<https://doi.org/10.1007/s11577-024-00951-5>>.
- Landecker, H. (2024). Life as Aftermath: Social Theory for an Age of Anthropogenic Biology. *Science, Technology, & Human Values*, 50, 4, 679-712. <<https://doi.org/10.1177/01622439241233946>>.
- Levins, R., Lewontin, R.C. (1985). *The Dialectical Biologist*. Harvard University Press.
- Marlatt, V. L. et al. (2022). Impacts of Endocrine Disrupting Chemicals on Reproduction in Wildlife and Humans. *Environmental Research*, 208, 112584.
- Margulis, L. (1990). Words as Battle Cries: Symbiogenesis and the New Field of Endocytobiology. *BioScience*, 40, 9, 673-677.
- Margulis, L., Sagan, D. (1997). *Slanted Truths: Essays on Gaia, Symbiosis, and Evolution*. Springer.
- Maturana, H.R., Varela, F.J. (1980). *Autopoiesis and Cognition*. D. Reidel Publishing Company.
- Meneganzin, A., Pievani, T., Caserini, S. (2020). Anthropogenic Climate Change as a Monumental Niche Construction Process. *Biology & Philosophy*, 35, 38. <<https://doi.org/10.1007/s10539-020-09754-2>>.
- Merlo, A., Barandiaran, X.E. (2024). Beyond Fatalism: Gaia, Entropy, and the Autonomy of Anthropogenic Life on Earth. *Ethics, Science & Environmental Politics*, 24, 61-75.
- Nicoglou, A., Merlin, F. (2017). Epigenetics: A Way to Bridge the Gap between Biological Fields. *Studies in History and Philosophy of Biological and Biomedical Sciences*, 66, 73-82.

- Nuño de la Rosa, L., Pavličev, M., Etxeberria, A. (2021). Pregnant Females as Historical Individuals: An Insight from the Philosophy of Evo-Devo. *Frontiers in Psychology*, 11, 572106. <<https://doi.org/10.3389/fpsyg.2020.572106>>.
- Parsons, K.J. (2021). Conservation Biology Meets Evo-Devo: How Understanding the Emergence of Variation Can Inform its Management. *Evolution & Development*, 23, 4, 269-272.
- Pearce, T. (2010). From ‘Circumstances’ to ‘Environment’: Herbert Spencer and the Origins of the Idea of Organism-Environment Interaction’. *Studies in History and Philosophy of Biological and Biomedical Sciences*, 41, 3, 241-252.
- Pearce, T. (2014). The Origins and Development of the Idea of Organism-Environment Interaction, in G. Barker, E. Desjardins, T. Pearce (eds), *Entangled life*. Springer, 13-32.
- Pontarotti, G., Dussault, A. C., Merlin, F. (2022). Conceptualizing the Environment in Natural Sciences: Guest Editorial. *Biological Theory*, 17, 1, 1-3. <<https://doi.org/10.1007/s13752-021-00394-7>>.
- Sanger, T.J. (2021). Integrative Developmental Biology in the Age of Anthropogenic Change. *Evolution & Development*, 23, 4, 320-332.
- Seebacher, F. (2022). Interactive Effects of Anthropogenic Environmental Drivers on Endocrine Responses in Wildlife. *Molecular and Cellular Endocrinology*, 556, 111737.
- Sogabe, A., Takatsuji, K. (2021). Marine-dumped Waste Tyres Cause the Ghost Fishing of Hermit Crabs. *Royal Society Open Science*, 8, 10, 210166.
- Walsh, D. (2015). *Organisms, Agency, and Evolution*. Cambridge University Press.
- Warde, P., Robin, L., Sorlin, S. (2018). *The Environment: A History of the Idea*. Johns Hopkins University Press.
- Wolfe C. (2026). Organisms as Meaning Makers, in K. Kull, D. Favareau (eds), *Toward a Biosemiotic Theoretical Biology*. MIT Press, 45-62.



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– ‘Environment’ as Interdependent Surroundings

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ABSTRACT

The idea of ‘environment’ is reconsidered by comparing a view of it as surroundings with one that sees it as a network of relations through which organisms constitute one another. Drawing on insights from developmental plasticity, symbiosis, epigenetics, ecological networks, and niche construction, this paper argues that organisms shape not only their own conditions of existence but also those of other species, generating multilayered surroundings rather than a singular environment. This framework is applied to anthropogenic evolution, where human activities restructure the developmental, ecological, and evolutionary contexts of countless organisms. By integrating perspectives from the Modern Synthesis, evo-devo, and niche construction, the paper shows that human-driven changes exemplify environmental entanglement and interdependent surroundings, challenging traditional boundaries between organism and environment and motivating a more relational ontology of life.

KEYWORDS

Surroundings: Entangled life; Milieu; Anthropogenic evolution; Evo-Devo; Niche construction

SOMMARIO

L’ambiente come il circostante interdipendente. L’idea di ‘ambiente’ viene analizzata attraverso un confronto tra una visione che lo identifica con il circostante ed una che lo intende come rete di relazioni attraverso la quale gli organismi si costituiscono l’uno con l’altro. Si argomenta, a partire dalle nuove conoscenze sulla plasticità dello sviluppo, la simbiosi, l’epigenetica, le reti ecologiche e la costruzione di nicchia, che gli organismi plasmano non solo le proprie condizioni di esistenza ma anche quelle di altre specie, generando un ‘circostante’ multistratificato e non un singolo ambiente. Integrando le prospettive della Sintesi Moderna, di evo-devo e della costruzione di nicchia, si mostra che i cambiamenti antropogenici sono un esempio di entanglement ambientale e di ‘circostanti’ (*surroundings*) interdipendenti. In contrasto con i confini tradizionali tra organismo e ambiente, questa prospettiva supporta una ontologia della vita eminentemente relazionale.

PAROLE CHIAVE

Circostante; Vita interconnessa; Milieu; Ambiente; Evoluzione antropogenica; Evo-devo; Costruzione di nicchia