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Designing with fungi: proposition for a sympoietic biodesign

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Abstract: Due to the drastic transformations in the conditions for life that are occurring in the Anthropocene, a reevaluation of the ways of being and designing onto the planet is necessary. Therefore, it becomes crucial to overcome the supposed human-nature dichotomy, understanding and practicing their inseparability and interdependence. In the design field, biodesign offers an opportunity in the indicated direction (Myers, 2018; Langella, Fiume, 2023), opening up to creative activities that integrate biological systems. It could be observed that such integration can occur with other biological systems as the object of human design activity, but also as possible partners. In this work, it is intended to speculate on new design relations open to interspecific intimacies and guided by sympoiesis (Haraway, 2016), by "making-with" nature as a partner in coexistence and creation, and not as a resource. For this purpose, the paper presents an overview of the biodesign and multispecies design fields, some project-based references, and a design experience elaborated following the Research through Design (RtD) method and adopting a design approach inspired by Material Driven Design (MDD) (Karana *et al.*, 2015; 2018). In this experience we exercise the sympoiesis ideas and summon fungi, since creative work with fungi presents a potential for connection and enchantment with other forms of life.

Keywords: Biodesign - Multispecies-Design - Sympoiesis - Anthropocene - Interdependence - Fungi - Mycelium-composite - Creative-process - Research-Through-Design - Material-Driven-Design

[Resúmenes en castellano y en portugués en las páginas 150-151]

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Introduction

All beings inhabiting this planet maintain multispecies relationships and rely on basic elements that sustain life, its cycles and its endings. However, artificial artifacts created by humanity have led some Humans to initiate a process of disconnection and separation between what is nature and what is culture, minimizing the vital notion of interdependence (Latour, 2013; Danowski, Viveiros de Castro, 2014).

Starting from the premise of interdependence, this article presents new ways of approaching design practices through listening to and including other beings in the design processes and projects. It seeks pathways for a design that faces the challenges of coexistence on a planet undergoing intense transformations in life conditions related to global climate, social, and technological relationships. Hence, human-nature collaborations becomes a potential for addressing anthropocenic crises.

This article aims to explore in particular the collaboration with fungi, which are excellent partners for understanding the terrestrial ecosystem. Fungi evoke valuable metaphors about interspecies interdependencies, have different notions of time and space, and act as agents of decomposition – of the endings and new beginnings. They have been studied in the fields of biomaterials and biodesign, showing great potential for application in architecture and design.

Fungi were the catalysts that allowed previously aquatic organisms to transition to terrestrial ground. This habitat change was possible thanks to the collaboration between algae

and fungi, which transformed the terrestrial environment. Fungi provided nutrients from rocks and minerals and allowed the transport of water to the algae. This partnership led to the origin of plants (Sheldrake, 2020; Lutzoni et al., 2018). "What we call 'plants' are in fact fungi that have evolved to farm algae, and algae that have evolved to farm fungi" (Sheldrake, 2020, p. 133).

The algae-fungi partnership has already yielded much life. Lichen, also a product of this association, is a significant figure when we talk about symbiotic relationships *(See Figure 1)*. The outcome of collaboration between two distinct kingdoms enables existences in unimaginable conditions and challenges scientific hypotheses. Biologist Merlin Sheldrake points out, "To this day, lichens confuse our concept of identity and force us to question where one organism stops and another begins" (Sheldrake, 2020, p. 77).

Figure 1.
Francisca Alvarez, 2020, "Diarios de naturaleza" (Source: https://cargocollective.com/estudiocaracol/Diarios-de-naturaleza).

These observations help us reflect on the relationships between organisms and the idea of the individual. Symbiosis is defined by biologist Lynn Margulis as intimacy between organisms of different species. "Partners in symbiosis, fellow symbionts abide in the same place at the same time, literally touching each other or even inside each other" (Margulis, 1999, p. 2). Margulis (1999) believes that the world is made in symbioses; she developed the theory of endosymbiosis, suggesting that species evolution occurs more through collaboration than competition. All organisms depend on symbiotic relationships.

Recognizing our own existence as intricate and entangled with other beings can help us understand how impossible it is to separate humans from what we call "nature." We are interdependent with other biotic and abiotic beings and the ecosystem of which we are a part. Anthropologist Anna Tsing (2014, 2015) further elaborates on the topic with some questions:

> Who are we? Ninety percent of the cells in our bodies do not have a human genetic signature; they are bacteria. Yet they are with us, and we need them. Our bodies come to be through them. Beyond our bodies, we cannot survive without multispecies land-scapes. We become who we are through multispecies aggregations. We are more like mycorrhizal fungi than we imagine. This makes an enormous difference for our theories of 'human' action in the world. How can humans act as an autonomous force if our 'we' includes other species that make us who we are? […] **What might it mean for a multispecies aggregate to act upon the world?** (Tsing, 2014, p. 10, author's emphasis).

Learning to work and live consciously and dialogically with other beings is an opportunity to expand capacities, broaden possibilities, and find encouragement to "stay with the trouble" (Haraway, 2016, title) and to find "life in capitalist ruins" (Tsing, 2015, subtitle). Biologist and philosopher Donna Haraway suggests that "the task is to make kin in lines of inventive connection as a practice of learning to live and die well with each other in a thick present" (2016, p. 1).
From these inquiries and by inviting fungi to participate in design-making, the article proposes to seek approaches that demystify the design-with more-than-humans, bringing other designers and artists closer to the fertile possibilities of collaborative multispecies projects, already widely anticipated by Amerindian and Indian traditions. Through this journey, the article goes on to propose 'sympoiesis' as an adjective for design.

Biomimicry, biodesign and multispecies design

The intersection with biology has been evident in the history of design in various forms. This includes the use of natural materials combined with ancient construction technologies and practices that were later named in modern Western science of the late 20th and 21st centuries – such as biomimicry and biodesign. In biomimicry, bio- and ecosystems serve as inspiration for design solutions. Biodesign, in turn, incorporates and utilizes living systems as part of the design project.
Janine Benyus, a pioneer in biomimicry studies, argues that we need to be more attentive and learn from nature. She posits, "we face our current dilemma not because the answers don't exist, but because we simply haven't been looking in the right places" (2002, p. 16). She describes three manners in which we should be attentive to nature: as a model, as a measure –or parameter for validating innovations–, and as a mentor. In her words, "we come not to learn *about* nature so that we might circumvent or control her, but to learn *from* nature, so that we might fit in, at last and for good, on the Earth from which we sprang" (2002, p. 17).
Biodesign distinguishes itself from biomimicry by inherently including living organisms as integral elements of design projects and product manufacturing. William Myers, author of the book "Biodesign: Nature + Science + Creativity," asserts that biodesign extends beyond nature-inspired innovation by referring to the

> incorporation of living organisms or ecosystems as essential components, enhancing the function of the finished work. It goes beyond mimicry to integration, dissolving boundaries between the natural and built environments and synthesizing new hybrid typologies (Myers, 2018, p. 8).

An example of biodesign is the use of fungal mycelium as a matrix for composite materials in the manufacturing of products such as packaging, construction materials, and acoustic panels *(See Figure 2)*. Biology describes mycelium as a network of hyphae that grows and absorbs nutrients in a pattern akin to networks. When we provide nutrients in a specific configuration, the fungal mycelium grows and expands along the organic matter, colonizing and decomposing it as it structures itself. If the fungus is halted in its colonization process by heat, it stabilizes, and the composite gains properties from both the substrate and the mycelium. The result is a material that is lightweight, biodegradable, non-toxic, waterproof, and possesses thermal and acoustic insulation properties. Considering this behavior and properties, researchers from various fields, including design, architecture, engineering, and biotechnology, have been exploring ways to shape and grow human-use products utilizing this mycelial technology.

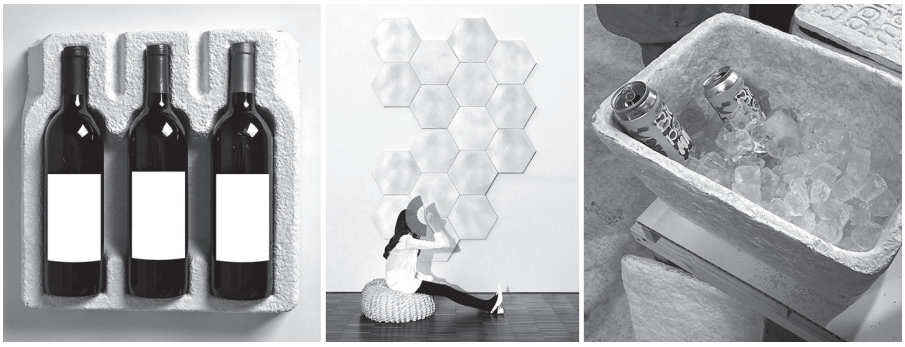

Figure 2. From left to right: Wine packaging by Ecovative (Source: https://www.ecovative.com); Acoustic panels by Mogu (Source: https://mogu.bio); Cooler by Radial (Source: author's archive).

The use of fungi as material components and the processes involved in growing them, fall within the scope of biodesign. The objects depicted in the images above are examples of biofabrication at large and medium scales, indicating the opportunity for alternative aesthetic understandings in relation to design tradition. Compared to the precision of geom-

etries and textures in modern design, living elements offer irregularity. In this direction, designers Carla Langella and Marcos Fiume developed the concept of Bio Ornamentum:

> The use of natural forms and structures in artefacts broadens the expressive possibilities of designers by offering a lexicon based on morphologies, tessellations, symmetries, but also discontinuities and inhomogeneities (Langella, Fiume, 2023, p. 24).

However, the opportunities promised by the field of biodesign are not only related to aesthetic paradigms in design but also to production and consumption models that, it is widely acknowledged, must change. In the face of the climate crisis we are experiencing, increased attention and care are crucial for a conscious, reflective, and respectful transition, especially when we intentionally involve other living beings. Myers warns, "disaster looms if new biological inventions simply accelerate the current cycles of environmentally destructive design and building in the relentless pursuit of short-term gains" (Myers, 2018, p. 17). A shift in perception of our needs and modern human lifestyles is essential, reevaluating the prioritization of economic concerns over socio-environmental issues.

When considering attention and care, we encounter the ethical debate that affects the processes and products involving living beings. How are the relationships between humans, non-human alterities, and technologies being established in the design processes? There are various approaches to incorporating living systems, but it is essential to consider how these relationships are built. When the main focus is solely on human well-being and on demands of human organizations and economies, there is a tendency to hierarchize systems, creating a dynamic of functional use and exploitation of other organisms involved in the project. The threshold between use and collaboration is delicate, complex, and often controversial.

The field of biodesign, in particular, faces this ethical challenge. While it offers opportunities for integrating ecological, biotechnological, and design processes, it also presents the risk of reducing living beings to mere resources or tools for human objectives, overlooking the fact that human well-being is deeply intertwined with ecosystem health. Being attentive to these issues with sensitivity and responsibility leads to practices consistent with a design that contributes to mitigating anthropogenic effects on the biosphere.

In this direction, it becomes necessary to develop and practice more critical and reflective approaches. With the intention of clarifying the distinction between using living organisms in design, and the proposal of collaboration with other species, new naming suggestions have emerged. In this article, we will introduce "designing and living with organisms" by Keune (2021); "multispecies design" by Metcalfe (2015); and "mycelial design" by Biz *et al.* (2021).

To conceptually differentiate the fields of design that work with living organisms and their levels of availability for interaction, designer Svenja Keune (2021) creates a graphic representation *(See Figure 3)* distinguishing the levels by color.

Figure 3.
A graphical representation of the conceptual framework that relates nature inspired approaches with biodesign and multispecies perspectives (Source: Keune, 2021, p. 18).

The outer green section represents approaches inspired by nature, such as biomimicry; the intermediate pink area signifies biodesign, where beings are more closely integrated into the project, often in a relationship of use. Between the pink area and the central yellow zone lies a transitional zone, where the author places verbs such as designing for, making-with, and thinking with care. This transitional area paves the way for more ethical relations that consider multispecies perspectives and embrace "multiespecies philosophy" (Keune, 2021). The yellow zone epitomizes the idealization of Multispecies perspectives. Terms like becoming-with, living-with, and staying-with are central to Keune's discussion, proposing the weaving of entangled multispecies worlds through design and coexistence.

Keune (2021) argues that in many biodesign processes, the living organism is seen as a workforce, executing a task dictated by the designer through its metabolism, thus missing the opportunity to understand the organism's creative abilities. She states: "the potentials of the living organisms are limited to the intention and imagination of the designer" (Keune, 2021, p. 5).

Another factor distinguishing biodesign from multispecies perspectives is the work environment and the emotional and physical distance maintained from the living being involved. In biofabrication processes, direct contact is often avoided to prevent contamination, striving to keep the workspace as clean, sterile, and safe as possible, distancing the organism from its typical relations and habitats (Keune, 2021).

In this vein, the design studio Aléa Work, seeking more integrated ways of working with fungi, proposes the cultivation of mycelium directly from the soil and describes their working methodology as bio-inclusive – a concept borrowed from environmental philosopher Freya Mathews (Aléa, 2024). The project "back to dirt" *(See Figure 4)* by Miriam

Josi and Stella Lee Prowse, from Aléa Work, proposes working with mycelium on-site, as a means to incorporate the interrelations that exist in the mycelium growth process. Aléa Work explores new design practices that can benefit multispecies landscapes (Aléa, 2024).

Figure 4. On the left, Dirty Chair N.4 sprouting mushrooms, 2023. On the right, preparing the soil to grown the mycelium chair (Source: http://aleawork.com/back-to-dirt-mycelium).

According to designer and researcher Carole Collet (2017), merging the skills of the designer with the living organism is a principle for collaboration and sharing the design process. The designer is tasked with creating an environment and conditions to negotiate with the living beings they wish to work with. The living organism then responds, or not, to the conditions offered by the human designer, and both adjust and engage in the transformation of things/objects/artifacts (Keune, 2021; Collet, 2017).

Engaging with other living beings generates sensitivity and empathy, as well as different reflections, thoughts, viewpoints, and forms of engagement previously unexperienced, only possible with practical involvement with one another. Moreover, working together in this proposition implies relationships of care that are particular to these design practices, triggering greater attention and responsibility (Keune, 2021; Mattern, 2018).

The use of the Përisi fungi *(Marasmius yanomami)* by Yanomami women in basketry is a fine example of practices of care, coexistence, and making-with. Although it does not involve growth as in biodesign practices, there is a practice of care with the forest that allows the healthy growth, and the continuity of the cycles of the fungi they use for weaving *(See Figure 5)*.

Figure 5. Përisi (Marasmius yanomami) and Përisi basket process (Source: Yanomami et al., 2019, p. 33, p. 14, and cover).

With an understanding of territorial preferences, climatic conditions, and symbiotic interactions, the Yanomami women, who hold knowledge of the Përisi, have a clear notion of where, when, and under what conditions to collect their raw material without affecting the availability and well-being of the fungus. The Yanomami women state, "we never take all the Përisi threads and also leave the new ones to keep growing" (Yanomami *et al*., 2019, p. 38).

The collection of Përisi in the forest is accompanied by the gathering of food, and the baskets used are the same ones made by the women from the vine and the rhizomorph of Përisi. This intricate relationship between crafting, living, and eating harks back to Keune's (2021) concept in Designing and Living with Organisms, and resonates with Haraway's (2016, p. 11) notion of *cum panis* –companion species at table together– a metaphor of care. It is a practice that goes beyond using the fungus as raw material and is part of the daily life of the artisans.

Furthermore, for the Yanomami, the relationship of respect and responsibility with what is used in the forest extends beyond an understanding of natural dynamics; it also involves the spiritual plane of protective entities:

> For us Yanomami, there is a protector of the forest, whose hair is the vine Too toto and the Përisi are her pubic hairs, while the insects, spiders, and snakes that live in the floorleafs are her lice. She protects the resources of the forest and therefore, when we take her hair and her pubic hair, we need to do so carefully and make the most of it, without letting the Përisi threads spoil. [...] To not offend the protector, we rotate the areas where we collect the Përisi. [...] We do the same with the vine. That way, the Përisi and the vine do not end, and the protector does not become angry (Yanomami *et al.,* 2019, p. 23).

Academia often seeks to develop and refine concepts and methodologies to connect and apply practices that naturally occur in traditional communities; such as the basketry work of the Yanomami women with the rhizomorphic threads of Përisi. The connection with the environment and respect for the forest's protective entities are cultivated by these communities and passed down to subsequent generations, who grow imbued with this wisdom and sensitivity to listen and coexist with the beings around them (Krenak, 2019; Yanomami *et al*., 2019; Kopenawa; Albers, 2015; Bispo dos Santos; Pereira, 2023).

Recognizing, respecting, and even being inspired by these ways of life is fundamental within academia to strengthen ecological thinking and the importance of other perspectives and ontologies. In Brazil, Ailton Krenak (2019, 2020, 2022) and Nego Bispo (2023) have gained an essential space in popular and scientific discourse that forces the horizons to open up for the consideration of various existing sciences.

The mycelial design described by designers Pedro Biz, Diego Costa, Pedro Themoteo, Flávia Soares, Bárbara Szaniecki, and Zoy Anastassakis is a "speculation about the possibility of a design in conjunction with all forms of life" (Biz *et al.,* 2021, p. 6). It is a study that unites biodesign, co-design and sustainable design. The authors use mycelium as a metaphor for its behavior as "a tangle of hyphae that spreads through a substrate and enters into symbiosis with plants, bacteria, and other fungi [...], a tangle of symbiotic life" (Biz *et al.,* 2021, p. 6).

The authors observe that in mycelial design, expectations regarding the designer's envisioned form are often disrupted as various agents influence the project's trajectory. They draw on Donna Haraway's concept of sympoiesis (2016) and Tim Ingold's idea of correspondence (2016) to conceptualize the shared, non-linear processes with unfinished results, always in transformation and collective action with the environment. In this context, "design is just another thread in an ever-flowing weave, operating in the time when the knots intertwine" (Biz et al., 2021, p. 8). According to the authors, "both Haraway and Ingold advocate for a horizontal relationship among beings where making is shared, intertwined, attentive, responsive, and responsible" (Themoteo *et al*., 2017, p. 6 apud Biz *et al.*, 2021, p. 8).

The shift from a human-centered approach to a design practice that considers the needs of other life forms is addressed by Daniel Metcalfe (2015). He proposes a design that is mindful of the needs of non-human animal species and works to benefit them.

> Rather than focusing only on minimising the negative effects that design has on other species (and the planet in general), this thesis looks at the possibility of intentionally addressing, within a design context, the needs of by promoting and improving their integration into human-dominated habitats (Metcalfe, 2015, p. 3).

The author poses questions that help to better understand multispecies design: "What role does the field of design have in facilitating the shift towards more bio-diverse human habitats?" and "what conceptual and practical tools are needed to develop the field in this direction?" (Metcalfe, 2015, p. 8). Therefore, the author works towards a design that allows the reconciliation of humans with other animal species. Metcalfe (2015) asserts:

> When designing for wild animals we expect animals to modify and customize the artefact as they interact with it. This process blurs the lines not only between designer and client but also between process and outcome (Metcalfe, 2015, p. 129).

He then questions the feasibility of designers adopting and cultivating qualities such as constant evolution and the "imperfections" caused by multispecies interference in the design project (Metcalfe, 2015). These interferences could be from other living organisms, such as animals and bacteria, or from abiotic entities, like rain, wind, time, and climatic conditions. Are designers willing to consciously incorporate into their projects situations that are beyond their reach and control?
On this aspect, we can take as an example the Modular Artificial Reef Structure (MARS) by the Reef Design Lab *(See Figure 6)*.

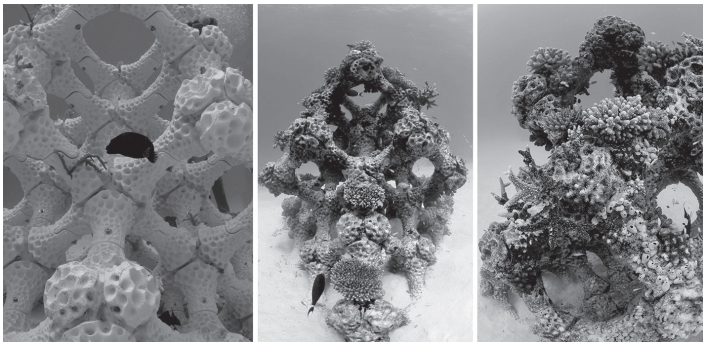

Figure 6.
Reef Design Lab, 2018, "MARS-Modular Artificial Reef Structure" (Source: https://www.reefdesignlab.com).

MARS modules are 3D printed and shaped with biocompatible and porous ceramic materials, reinforced with steel, that facilitate the transplantation and development of corals. Being modular, MARS allows the construction of marine systems tailored to the specificities of environments and restoration objectives (Reef Design Lab, 2024).
The creation of these structures aims to maintain and recover the biodiversity of marine ecologies. The project takes into account potential alterations by animals, algae, and various organisms within aquatic ecosystems as they inhabit and interact with the systems. These interferences, as can be seen in *Figure 6*, are extremely vivid and aesthetic.
Regarding multispecies practices, Metcalfe ensures that:

> The shift in design practices to include more attention to the needs of wild animal species represents a way of both sustaining more biodiversity within human-dominated habitats, and creating more opportunity for humans to interact with other species in a meaningful and respectful way (Metcalfe, 2015, p. 4, author's emphasis).

Given the complexity and transformations that the field of design is undergoing, the necessity for more conscious approaches to multispecies interactions and landscapes becomes evident. Concepts such as biomimicry, biodesign, mycelial design, designing and living with organisms, and multispecies design provide relevant insights where attempts to move beyond the predominant Western anthropocentric view and to acknowledge the significance of symbiotic relationships in an ethical and ecosystem-integrated approach to design.

Sympoiesis as an adjective for design

Beth Dempster (1998) was the first to use the term simpoiesis. Her environmental studies dissertation was dedicated to differentiating poietic systems, defining sympoietic systems as:

> collectively-producing systems that do not have self-defined spatial or temporal boundaries. Information and control are distributed among components. The systems are evolutionary and have the potential for surprising change (Dempster, 1998 apud Haraway, 2016, p. 61).

Donna Haraway (2016) then brought the term to wider attention, fostering its adoption in a range of contexts, including design, to suggest a radical shift in how we conceive the "making" and the interactions with the living world. Studying sympoiesis challenges us to rethink not just the products of design but also the underlying practices and ethics, seeking an environment of harmony and respect among the forms of life involved in the project. Thus, we delve into a profound reflection on the role of design in building a more interconnected, collaborative, responsive, and diverse world.

Here, we seek to understand the term as an adjective for design, one that can suggest ways of practicing design on the principles of sympoiesis. In a very simple way, the term refers to a making or creating (poiesis) that is intricate, intimate, and collective (sym – from symbiosis).

Sympoiesis is used by biologist and philosopher Donna Haraway (2016) as an update and expansion of the notion of autopoiesis (Varela, Maturana, 1974). Autopoiesis is a type of creation or making (poiesis) of oneself (auto), characteristic of living systems. For Haraway (2016), autopoiesis would be insufficient for the living models of entangled exchanges and associations that occur in all making (poiesis). According to the author:

> Mortal Worlds (Terra, Earth, Gaia, Chthulu, the myriad names and powers that are not Greek, Latin, or Indo-European at all) do not make themselves, no matter how complex and multileveled the systems, no matter how much order out of disorder might be produced in generative autopoietic system breakdowns and relaunchings at higher levels of order (Haraway, 2016, p. 33).

Haraway then suggests changing the prefix auto to sym, to broaden the sense of the initial concept:

> As long as autopoiesis does not mean self-sufficient "self making," autopoiesis and sympoiesis, foregrounding and back-grounding different aspects of systemic complexity, are in generative friction, or generative enfolding, rather than opposition (Haraway, 2016, p. 61).

This passage elucidates that the question of changing prefixes is much more about focusing on different aspects of the poiesis and complex systems. In sympoiesis, what is highlighted for the functioning and organization of systems are the exchanges and interdependencies, and in autopoiesis, it is the systems' capacity for autonomy and the definition of autonomous singular units. However, both terms embrace the complexities of living systems. Haraway feels the need for the term to speak about Terran dynamics, living systems, and beings that she names as tentacular:

> The tentacular ones make attachments and detachments; they make cuts and knots; they make a difference; they weave paths and consequences but not determinisms; they are both open and knotted in some ways and not others (Haraway, 2016, p. 31).

Sympoiesis speaks of dynamic, open, complex, and responsive systems: "poiesis is symchthonic, sympoietic, always partnered all the way down, with no starting and subsequently interacting 'units'" (Haraway, 2016, p. 33).

The prefix 'sym' originates from symbiosis, living together. A symbiotic relationship is defined when organisms of different species share the same space and time, touching or even inside one another, sharing processes, living together (Margulis, 1999). All organisms rely on symbiotic relationships, not all of which are positive or symmetrical. Symbiosis is a joint dynamic that enables life, making organisms capable of learning to be in and with the world. Practicing sympoiesis would be to recognize and pay attention to how we make the world together.

A design based on the principles of sympoiesis speaks much about attentive making, involving the body, mind, and matter. It is about being aware of partnership opportunities. It is to understand that projects do not end when the designer stops acting upon them, as many transformations continue to occur concerning time, material, other involvements, etc. (Ingold, 2022; Metcalfe, 2015; Haraway, 2016; Keune, 2021).

For designer Barbara Szaniecki, "Sympoietics is revealed, then, as a 'making with' that is also a living and struggling with others. The 'making with' leads us to think of a 'design