LIVING WOOL

Co-Creating With Mycelium and Wool in Sustainable Practice

LAPIN YLIOPISTO
UNIVERSITY OF LAPLAND

Living Wool

Co-Creating With Mycelium and Wool in Sustainable Practice

Master's Thesis

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Abstract

This thesis explores sustainable material practices through the investigation of mycelium and wool as bio-based design materials. Motivated by the idea of material self-sufficiency, the research examines how discarded or overlooked resources can be repurposed in regenerative, locally rooted ways. Using an autoethnographic approach, the study combines hands-on experimentation with theoretical reflection over a five-month period that included an internship and visiting research, followed by extended post-research analysis from a post-humanist perspective. The work investigates the technical, cultural, and methodological aspects of combining wool with mycelium—a living organism—highlighting how this collaboration repositions the designer from passive material selector to active cultivator. Emphasising care, adaptability, and co-creation, the study explores how working with living materials transforms both process and mindset. Exhibitions held in Finnish Lapland provided insights into audience perception and the ethical implications of these materials while encouraging the imagining of future applications. Ultimately, the study contributes to emerging bio-art and sustainable design practices by expanding the material vocabulary available to artists and designers, and by promoting more reciprocal relationships between humans and nature.

Keywords: mycelium, wool, sustainable materials, bio-based design, autoethnography, posthumanism, bio-art

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Glossary

Algae
Simple, often aquatic organisms that use photosynthesis. Some species are used in bio design for regenerative or material properties.

Assemblage
A collection of diverse elements—human, non-human, living, and non-living—interacting within a system.

Benchmark
A standard or reference point used to evaluate performance, results, or progress.

Bio art
An art practice using living organisms or biotechnology, often to question ethical or scientific norms.

Biodesign
A design approach that integrates biological systems into materials, products, or environments.

Bioethics
The study of ethical issues in biological research and life sciences.

Cavities
Hollow or empty spaces within a form are often explored for function or aesthetics.

Citizen Science
Research conducted by or with the participation of non-professionals or the public.

Cohabitation
Living together in shared space, often referring to multispecies collaboration.

Colonise
The process by which fungi grow and spread across a substrate.

Composite
A material made from two or more components, each retaining its properties but working as a whole.

Contamination
The presence of unwanted substances or organisms in a controlled experiment.

Cross-fertilization
Exchange of ideas or biological material across fields or species.

Cross-pollination
Transfer of concepts between disciplines or fields to stimulate innovation.

Cultivation
Growing and maintaining living organisms in controlled conditions.

Cultures
Populations of microorganisms or cells are grown for research or design.

Decay
The breakdown of organic material is often embraced in sustainable design.

DIY (Do-It-Yourself)
A self-directed, hands-on approach without relying on institutions.

Dormant
A temporary state of inactivity in a living system.

Entanglement
Interconnectedness between different beings, materials, or systems.

Façade
The external surface of a structure; also refers to material skins.

Fruiting phase
The stage where fungi produce mushrooms or fruiting bodies.

Fungal
Related to fungi

Fungi
A kingdom of organisms including moulds, yeasts, and mushrooms.

Fungus
Singular of fungi.

Growing chamber
A controlled environment is used to cultivate organisms like fungi.

Immersive
Thoroughly engaging or sensory-rich experience.

In situ
Latin for “in place”; refers to natural or intended context.

Infancy
The early stages of a process or experiment.

Inoculation
Introducing spores or spawn into a substrate to initiate growth.

Interwoven
Physically or conceptually woven together.

Kinship
Relational ties extended beyond humans to include other species.

Low-threshold
Easy to access, requiring minimal resources or expertise.

MBC (Mycelium-Based Composite)
A lightweight, biodegradable material made from fungal mycelium and substrate.

MDD (Material-Driven Design)
A design approach where material properties drive the design process.

Mould or mould
Container to cast shapes

Mould or mould (fungi)
Associated with the deterioration of food or manufactured goods of organic origin

More-than-human
A perspective that recognises non-human agency in ecosystems.

Mutation
A change in genetic or structural characteristics; also metaphorical for transformation.

Mycotecture
Architecture or structures made using fungal mycelium.

Non-human
Any agent or being that is not human.

Odd kin
A term from Donna Haraway meaning unlikely or cross-species kinship.

Pinhead
The tiny initial stage of mushroom development.

Posthumanism
A theory that critiques human-centred thinking and embraces non-human agency.

QR (Quick Response) Code
A scannable digital code linking to multimedia or web content.

Reincarnation
Material or symbolic rebirth into a new form or function.

SCOBY
A symbiotic culture of bacteria and yeast is used in fermentation and materials.

Skinning phase
A phase in fungal growth where a surface skin forms.

Slime mould
An intelligent, amoeba-like organism used in experimental design.

Spawns
A starter material containing mycelium used for inoculation.

Spores
Reproductive cells of fungi that initiate growth.

Strain
A genetic variant of a microorganism (such as fungi) that shows consistent traits, like growth behaviour or resistance to contaminants.

Substrate
The material on which fungi grow and feed.

Tinkering
Iterative, hands-on experimentation and problem-solving.

Zoning
Dividing space or phases into designated functional areas.

1. Introduction

This chapter introduces the groundwork of the research by tracing how a personal and material curiosity evolved into a sustained artistic investigation. It outlines the motivations behind working with mycelium and wool, as well as the questions that guided the process. Framed within ongoing conversations around sustainability and material agency, the chapter also presents the research aims and methodological orientation, while mapping out the timeline of the work. Like mycelium threading through soil or wool spun into form, the ideas and methods developed here are interwoven—each part contributing to a broader network of meaning that unfolds throughout the thesis.

1.1. Context and Motivation

In 2020, I vividly recall the COVID-19 pandemic disrupting not only my daily routines but also the larger systems I usually depend on. Like others, I witnessed the breakdown of agro-food distribution networks, which raised public awareness about food security and local self-sufficiency (Rahman et al., 2022, p. 2). There was a trending phenomenon when people began to reconnect with nature—growing their own vegetables, sharing their plant-growing journeys, and reflecting on the fragility of global systems. These events struck a personal chord, not only as an individual but as a designer. It made me question: if households were rethinking food resilience at a micro scale, how might we—designers—rethink our dependence on industrial material systems? Could we also explore a form of material self-sufficiency?

Just like a faith, one question evolves to the next. My next turning point came not from a textbook but from the floor of my studio. During the early months of the pandemic, a small cluster of mushrooms began to sprout between the floorboards. Every week, my colleague and I would remove them, only to find them reappearing days later. At first, it was disturbing. But over time, what began as an irritation slowly became something else: a quiet provocation. I started observing them more closely—their persistence, their subtle intelligence, the way they returned no matter how many times we scraped them away. They were not just invaders; their resilience is admirable. It sparked a new question: What if materials could be grown, just like these mushrooms?

As my curiosity evolved, I discovered I was not alone in this line of thinking; many worldwide projects have been using this material. For example, NASA's Innovative Advanced Concepts (NIAC) programme has explored 'mycotecture' as a vision for future habitats on the Moon and Mars. Rothschild et al. (2022) describe how mycelium-based composites could be used to grow structure in situ, using fungal organisms that form building materials when fed with organic matter and water (p. 1). In space, the appeal is clear—autonomous, low-energy construction. But the potential is equally relevant here on Earth. If mycelium can grow buildings in extreme environments, why can't we embrace it as a serious material collaborator in sustainable design?

This question became the seed of my research. It opened up new perspectives about materials—not as static inputs, but as dynamic, living collaborators that could be grown, nurtured, and transformed. Borrowing from Assia Crawford (2022), this means placing human designers not above materials, but alongside them (p. 219). Materials, in this view, are not merely resources but actors with their own agency. From this train of thought, my interest in bio-based materials like mycelium began. It led me to pursue a Master's program in Sustainable Art and Design and eventually shaped the focus of this thesis.

Just like a seed needs soil to nurture its growth, mycelium also requires a substrate—a source of nutrients or food—to support its cultivation. It was at this point that Maria Huhmarniemi suggested exploring wool as a potential substrate. This direction was promising, as the integration of these materials is relatively underexplored, making this research a contribution to new material development. It motivated me to get involved in the VillaInno research team at the University of Lapland, a project focused on wool innovation.

According to RÄisÄnen (2019), during wartime, Finland experienced a rise in sheep farming due to import restrictions, positioning wool production as a vital part of the country's resilience strategy (p. 264). This historical precedent aligns with the motivation behind my research: the pursuit of material self-sufficiency. Yet, despite this historical legacy, today there is a growing surplus of unprocessed and discarded fleece (Cervantes, personal communication, July 27, 2025). It reported that up to 50% of Finnish sheep's wool currently goes to waste due to low market value and limited processing infrastructure (lapuankankurit, 2025). Other industry sources,

such as Myssyfarmi, estimate that over 60% of raw fleece ends up as waste, often burned due to limited market incentive (myssyfarmi, 2025). This contradiction has shaped my evolving design philosophy—prompting me to ask how overlooked or wasted resources might be reimagined as valuable, regenerative materials that are deeply rooted in local heritage.

Reflecting on years of experience in architecture, I never imagined working with soft, organic materials like mycelium or wool. My practice had always centred on hard, conventional materials—concrete, steel, brick. These industrial materials dominated my professional practice, and material selection typically occurred in the final stages of design. This is common in architectural workflows, but I've come to see it as a symptom of a passive design mindset—one that resists uncertainty and defaults to what is already proven.

Ahern and Kato (2008) argue that uncertainty is an inherent condition in working with complex systems like landscapes (p. 545)—and by extension, materials. Rather than avoiding it, we are encouraged to acknowledge uncertainty, engage with it, and develop strategies that treat design itself as a form of inquiry. Just like the planetary shifts we are experiencing—climate instability, ecological degradation, resource unpredictability—uncertainty is not something we can design our way out of; it must be designed with. In this context, the designer must become an active agent: someone who responds, experiments and adapts in close collaboration with material and ecological systems. Applying this to material practice means becoming more responsive and open to unfamiliar material behaviours. If we are to respond to the environmental crises of our time meaningfully, designers must shift from passive selection to an active maker, working with nature rather than against it.

This thesis, then, is not about designing or delivering a final product. Instead, it documents a process of exploration—an attempt to understand what happens when mycelium and wool meet. Through hands-on experimentation, this research aims to investigate how these two materials might be grown together and what kind of sustainable futures they might help design. In doing so, I hope to contribute to a new material palette for designers and artists—one that expands our ecological imagination, embraces care, and rethinks what it means to collaborate with materials.

1.2. Research Questions

The more I learn about the world of mycelium, the more mysterious it becomes. As Ostendorf-Rodríguez (2023) notes, fungi “throw up questions, never answers” (p. 6), making them a symbol of open-ended discovery. My interest lies in how materials can be understood not only through theory, but through making—cultivating, testing, failing, and adapting, much like fungi themselves. With this spirit of curiosity, the central research question guiding this thesis is:

How can mycelium and wool be explored as sustainable materials?

To address this overarching question, three sub-questions have been formulated to examine different aspects of the inquiry:

First, what kinds of workspace and processes are needed to support hands-on experimentation with mycelium and wool? Grounded in practical making, this question looks at the conditions required for cultivating this new hybrid material—both physically and creatively. What does a designer’s lab for growing materials look like, and what new skills or modes of attention does it demand?

Second, what insights emerge through practical, material-led experimentation with these two materials? Here, the focus is on the knowledge and understanding gained through direct interaction with the materials. This includes observations about the technical and experiential characterisation of the materials (Karana et al, 2015, p.41), revealing how the process of nurturing the materials informs the artistic process and direction.

Third, how do people’s responses to these materials inform critical reflection and their potential influence on future material innovation? Moving from practice to reflection, this question considers the broader implications of the research. It examines insights that arise not only from the maker’s perspective but also from the audience during exhibitions. This opens up ethical and philosophical questions about sustainability, bioethics, and post-humanist design, while considering future applications of wool–mycelium composites.

These questions frame the scope of this thesis and guide both the practical and theoretical components of the research. They reflect a material-led inquiry that values process, reflection, and public engagement as part of knowledge-making.

1.3. Aims, Approach & Timeline

At its heart, this thesis explores the intersection of material practice and sustainability through hands-on work with mycelium and wool. The aims of this explorative artistic research are as follows:

First, to investigate and define the physical and creative workspace requirements, as well as the processes, necessary to support hands-on experimentation with mycelium and wool. This aim focuses on understanding the practical conditions and skills that facilitate the cultivation and crafting of these hybrid bio-materials.

Second, to generate material knowledge and insights through direct, practical experimentation with mycelium and wool, examining their technical characteristics and experiential qualities. This aim addresses how material-led exploration contributes to the artistic process and informs design decisions, revealing the potentials and challenges inherent in working with these living materials.

Finally, to critically reflect on public and personal responses to wool–mycelium composites, assessing their ethical, cultural, and philosophical implications for future sustainable material innovation. This aim considers broader questions of bioethics, sustainability, and post-humanist perspectives, drawing from audience engagement during exhibitions and the researcher’s own reflective practice. Together, these aims respond directly to the research questions outlined in the previous section and structure the overall direction of this inquiry.

The significance of this research lies in its potential to expand sustainable material design by exploring the underutilised properties of mycelium and wool as bio-based composites. By combining hands-on experimentation with reflective practice, this study contributes both practical knowledge and critical ethical perspectives that can guide future material innovation. Furthermore, it fosters interdisciplinary collaboration

across design, biology, and technology, encouraging a more empathetic and responsible relationship between designers, living materials, and the broader ecosystem.

Initially, I intend to begin with an Art-Based Action Research (ABAR) approach, focusing on hands-on experimentation, responsiveness, and collaboration with living materials. However, I also anticipate that the process will become deeply personal and reflective, shaped by my own experiences as a maker. For this reason, I plan to shift toward an autoethnographic approach—a first-person, reflective method that positions the researcher as both subject and practitioner. This approach will become the central methodology of the thesis. A more detailed discussion of this methodological direction will be provided in Chapter 3.

The timeline of this research mirrors fungi's organic development, their universal yet deeply local presence. Fungi exist across the globe, adapting uniquely to each environment. Inspired by this quality of interconnected adaptability, I set out on a research journey to explore the potential of mycelium by learning from diverse people, places, and practices. Just as fungi form networks across varied ecosystems, I sought to build a similarly exploratory path.

My exploration will begin with an early involvement in the VillaInno project at the University of Lapland, where I will source raw wool and gain foundational insights into wool innovation in a northern context. Although this early phase will not involve the core practical material experiments, it will help to shape the context and materials for the research.

The practical experimentation phase will span approximately five months. It will begin with a three-month internship at Caracara Collective, a bio-design studio in Helsinki (March–May 2024), where I plan to develop foundational skills in cultivating and working with bio-based materials such as mycelium and wool. This will be followed by two months as a visiting researcher at the Biomaker Space at Aalto University (June–August 2024), where I will expand the explorations, integrating wool-based craft techniques with fungal growth in a shared studio/lab environment.

In parallel, I will pursue an exchange study at the University of Copenhagen (August 2024–January 2025), where I will engage more deeply with the theoretical, aesthetic

and cultural dimensions of materiality and climate change. Although this phase will not involve physical experiments, it will significantly enrich the conceptual framework of the thesis through coursework, workshops, site visits and literature review.

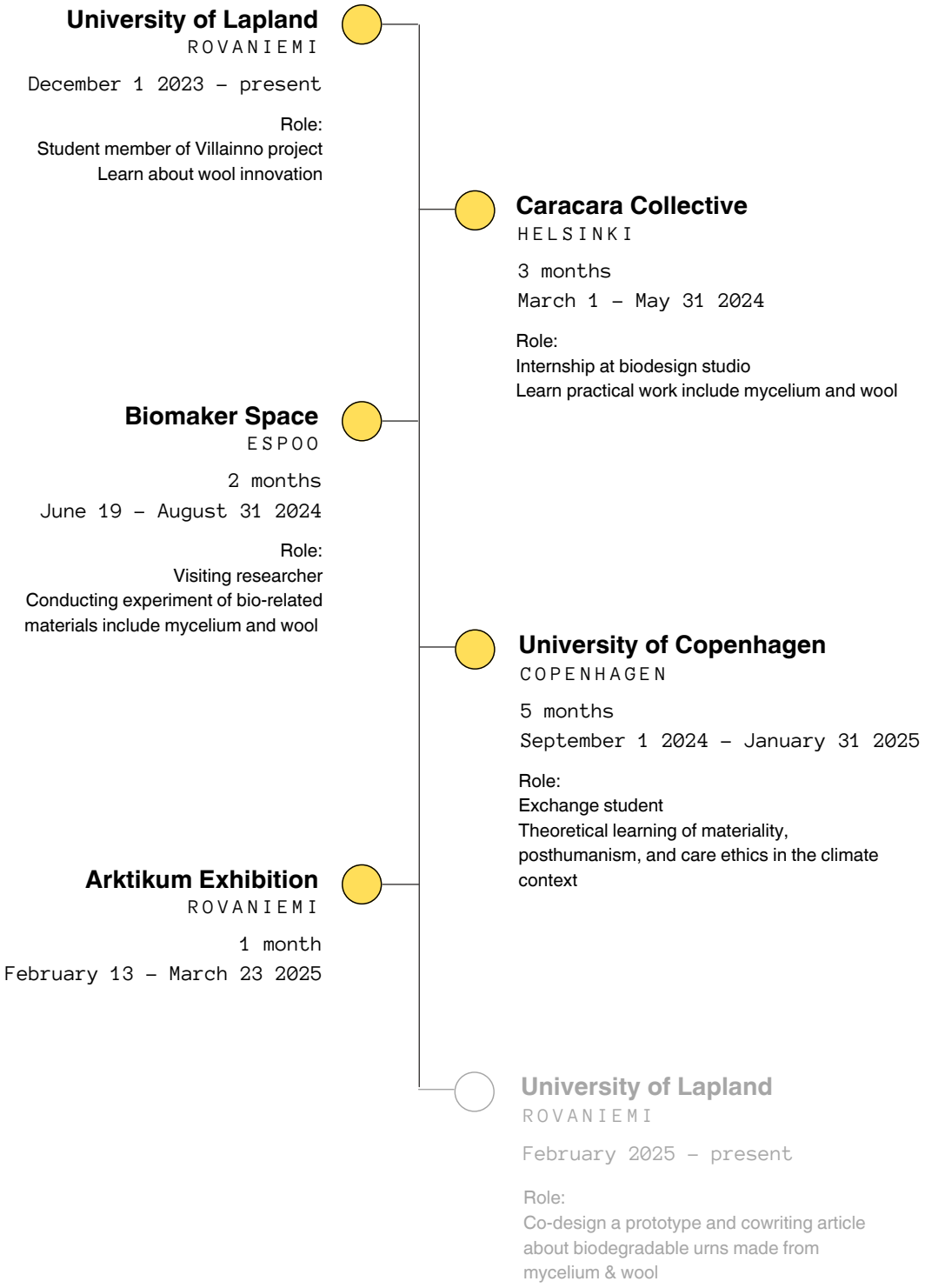
Toward the end of the research process, I will present selected outcomes in a public exhibition at Arktikum. This exhibition will provide a valuable space for dialogue and reflection, offering insight into how audiences interpret and interact with emerging materials. Their responses will add new perspectives not only to my perspective but also to public perception, encouraging further reflection on the ethical, cultural, and imaginative possibilities of working with bio-based composites.

This thesis marks an early milestone in my growing design practice and forms a foundation for future research. As part of the Villainno project, I will continue to engage in a co-design collaboration with Cervantes to develop biodegradable urns made from mycelium and wool. While this project represents a promising direction for applied material innovation with these materials, it falls outside the scope of this thesis. It will be addressed in a separate publication.

Overall, this journey reflects fungi's adaptability—local yet interconnected—mirroring the collaborative nature of material exploration. The table on the next page outlines the phases of this research journey. The yellow circle highlight the periods central to this thesis; otherwise, they fall outside the scope of this particular study.

Figure 1

Research Timeline [Arrafiani, 2025]



Throughout the writing process, AI tools were used to enhance clarity, refine language, and support structure. The author independently developed all content, analysis, and theoretical frameworks.

2. Theoretical Framework

This chapter will discuss the key theoretical construct as a framework for my artistic explorations. As a human and a designer newly entering the realm of designing with living organisms, this theoretical framework serves not only as basic guidance but also as an invitation to think with and alongside non-human entities. It weaves together insights from theorists, researchers, and artists, including the phenomena and current state of the research in this field. More than general guidance, it is also a space of reflection and offers ground knowledge for the readers.

2.1. About Sustainability, Bio-Art and Growing Design

Sustainability is often seen as a buzzword, frequently used in everyday life, in design, policy, and even marketing. Many people around the globe are increasingly aware that our planet is heading towards critical destruction, and we are trying to understand what sustainability is. In fact, I chose to major in sustainable art and design because I was interested in this issue. What truly constitutes a sustainable designer? I was once asking myself.

Sustainability in design is beyond aesthetic and functionality. Today, we become aware that it links to the broader context of ecological, cultural and systemic impacts. One of the significant aspects of sustainable practice is to use and select green materials, with the aim of minimising environmental harm. Designers need to acknowledge that design is not only about nice objects but also the system behind it. As Egenhoefer (2018) emphasises, design should not be understood only by its physical outputs—whether it's fashion, graphic, web, or architecture—but also about the cultural associations, economic systems, and the politics that are connected to global systems (p. 1). Designers must engage with these holistic systems to achieve sustainable outcomes.

Tsing (2015) asserts that the advent of modern capitalism has a direct influence on long-term landscapes and ecological destruction (p. 19). Often unintentionally, designers contribute to this environmental degradation, particularly when they prioritise short-term convenience over long-term ecological impact. Without proper systemic awareness, the design solution risks losing its vision and the problem it seeks to solve. Today, design must address the unintended consequences of its

outputs. Wright & Ceroni (2018) note that systemic thinking provides a holistic design framework of what to make and how to make it, as part of a vision for more equitable and ecological futures (p. 15).

To understand how it's relevant to global connection, the United Nations introduced Sustainable Development Goals (SDGs)—a set of 17 goals adopted by 193 countries to address pressing global issues by 2030 (United Nations, 2025). This project engages explicitly with SDG Goal 12, which calls for sustainable consumption and production, including the development of environmentally responsible alternatives and innovations that minimise ecological impact (United Nations, 2025). In this context, I began to question whether my material experiments with mycelium align with these aims. Many scholars and practitioners believed that Mycelium, a fungal organism, have the potential to provide biodegradable and renewable materials. This aligns with Tiwari & Park's (2024) research: advances in fungal biotechnology hold potential to contribute significantly to climate mitigation strategies and support the SDGs (p. 12).

The use of living organisms is well established in industries like medicine, food, and packaging, and has traditionally been driven by top-down corporate and laboratory research. However, in the realm of art and design—and through my own observation—certain organisms, such as mycelium, remained niche and underexplored. This is slightly in contrast to Kac's (2007) statement, that living organisms in art have long been present, dating back to the early twentieth century (p. 11). As Kac (2007) notes, artists have experimented with living organisms, 'grown or bred in unique ways, modified or invented by artists', which he calls 'the elements of a true art of evolution' (p. 14).

Despite the historical precedent, it is only in recent years that there has been a noticeable interest among independent artists, designers, and academic researchers in cross-fertilisation of biology into artistic expression. These practices mark the rise of what is known under the umbrella term of bio-art*,* bio-design*,* or growing design*.* These three terms are often used interchangeably to define a similar creative process.

Bio-art is a new direction in contemporary art that manipulates the processes of life (Kac, 2007, p. 14). Beaudoin (2021) also asserts that the practice of bio art

potentially led to a deep reconfiguration of how human beings relate to the environment, offering productive avenues to engage with pressing ecological challenges (p. 165). These theories show the importance of cohabitation, kinship and deep re-connection between humans and non-humans to guard the ecological balance. Camere & Karana (2018; 2020) emphasise that it is evident concerns about sustainability are the primary reason behind designers' ambitions to incorporate living materials into their design practice (p. 39).

The emergence of bio-art is intertwined with the ongoing process of evolution (Pietarinen & Qureshi, 2024, p. 2). The potential for reproduction, replication, and death within these works (Kac, 2007, p. 19) means they may persist as long as life exists on Earth (Kac, 2007; as cited in Pietarinen & Qureshi, 2024, p. 2). If I can project through my lenses, designing with living organisms has similar natural processes as other life forms, such as mutation, adaptation, reproduction, and decay. It becomes more than conventional art; it participates in life's evolutionary path. For instance, if the organism in the artwork (like mycelium) can reproduce with sufficient nutrients, it may continue to live and evolve. If it dies—due to age or intentional design—it can decompose and re-enter the natural cycle, potentially fostering new life.

This interplay between human and non-human is also central in Karana et al.'s (2018) concept of Growing Design. In this approach (Camere & Karana, 2017; Ciuffi, 2013), designers cultivate materials from organisms such as fungi, algae, or bacteria to develop unique functions and sustainable outcomes. This reflects a non-anthropocentric approach, viewing living organisms not as tools but as collaborators.

According to Karana et al. (2018), growing design requires working closely with biological organisms—guiding their growth, exploring their properties, and shaping the conditions in which materials emerge (p. 119). Interestingly, the practice is closer to craft, as it is rooted in hands-on manipulation and making (Karana et al, 2018, p. 120).

What's compelling is how designers, beyond aiming for sustainability, find joy and even surprise in the co-creative process. As Camere & Karana (2018) note, "Designers perceive their practice as co-performed with an organism that has an agency of its own... which limits the intentionality of designers and makes the

outcome unpredictable" (Karana et al., 2020, p. 39). This unpredictability invites reflection on care, symbiosis, cohabitation, and adaptation. Similarly, Kac (2007) cites Yves Michaud, who sees bio-art not just as production, but as 'the creation of experiences' and the 'aestheticization of life' (p. 24)—suggesting that the act of making itself becomes an expressive, artistic journey.

2.2. Mycelium and Wool: State of the Art

Building on the foundations of sustainability and bio-art, this section turns toward the two core materials at the heart of this research—mycelium and wool. Both carry rich ecological, cultural, and symbolic meanings, particularly when viewed through the lens of growing design. This section introduces each material and examines how they function within contemporary design contexts. By benchmarking existing research and experimental projects that were combining these materials, this section highlights the emerging potential of their integration. Mapping their properties, uses, and precedents helps establish a foundation for the material experiments in this thesis.

Karana (2018) explains that mycelium consists of a network of interwoven, thread-like hyphae that form the vegetative structure of fungi (p. 121). In some fungal species, these networks develop into 'fruiting' bodies (i.e., mushrooms)—a term commonly used to describe the growth of mushrooms—possibly after the mycelium is formed. However, scientifically put, it is neither plant nor animal, but its own biological kingdom (Ostendorf-Rodríguez, 2023, p. 6).

Mycelium plays an essential ecological role, borrowing Ostendorf-Rodríguez's (2023) perspective, as a 'messenger' in forest ecosystems, facilitating communication between plant roots and other subterranean organisms, transporting nutrients, supporting plant regeneration and survival and acting as a natural binder (p. 7). Public awareness of mycelium reached new heights after biologist Suzanne Simard popularised the term 'wood wide web' in her book *Finding the Mother Tree*.

Despite the recent surge of interest, human relationships with fungi are ancient, as McCoy (2016) notes their roles in food, medicine, and customs, describing fungi as 'the world's greatest and oldest teachers' (p. XV). Indigenous Skolt Sámi, for

example, uses dried fungus for medicinal purposes (Mutsonen, 2020). More recently, mycelium has drawn attention as a sustainable material for everyday artefacts such as chairs, tables, lampshades and so on (Karana, 2020, p. 29). Mycelium cultivation depends on optimal conditions. Most species thrive at a range of temperatures, but most grow best around 70°F or 21°C (McCoy, p. 204). Humidity levels should remain around 60–65% to prevent substrate dehydration (Carlile et al., 1994). Darkness is also favourable for the rapid growth of mycelium as well as to avoid the formation of the ‘fruiting’ bodies (Deacon, 1980). Once fully grown, the mycelium can either be deactivated by drying at a minimum of 60°C (Kavanagh, 2011) or preserved in a dormant state at room temperature for potential future use.

In a recent design application, Karana describes two methods for growing mycelium: (1) mycelium-based composites (MBCs) and (2) liquid culture harvesting (Haneef et al., 2017; Holt et al., 2012; as cited in Karana, 2018, p. 121). MBCs are fabricated by inoculating an individual strain of fungi in a substrate of organic substances (Holt et al, 2012). This research focuses on MBCs due to their potential use of organic waste as substrates, which addresses both material innovation and waste reduction. MBCs are generally easier to mould, more durable, and cost-effective than pure mycelium materials (Karana, 2018, p. 123). It commonly utilises agricultural waste as a substrate, such as wood chips, straw, or coffee residues. During my internship at Caracara Collective, we used vacuum forming plastic moulds, which is a common material and believed to be effective, as fungi (depending on the type) won’t ‘digest’ plastic. However, this traditional mould raises concerns due to its rigidity and environmental impact, as plastic can take hundreds of years to decompose.

In response, there has been a growing interest in exploring mould-free and soft-mould techniques that offer greater flexibility and biodegradability (Soh et al., 2020; Bitting et al., 2022; Elsacker et al.,2019). These innovative approaches aim to create a mould that not only shapes the growing material but also serves as part of the final product, ideally decomposing along with the mycelium. Among these, textile-based moulds are gaining increasing attention for their design adaptability and sustainable potential (Adamatzky et al., 2021; Biala & Ostermann, 2022; Dessi-Olive, 2022).

In Finland, textile products like wool hold cultural significance. Historically, the Sámi have long used hand-spun wool in household textiles (Koslin, 2010, p. 6), and the tradition of knitting, weaving and crocheting remains alive today, reflecting a rich

tradition passed through generations. Yet, large quantities of wool go to waste annually in Finland. Cervantes from VillaInno points out that many farms lack access to processing facilities, leading to an accumulation of unprocessed and waste fleece (Cervantes, personal communication, July 27, 2025). VillaInno aims to address these issues by fostering collaboration between universities, designers, researchers, farmers, and wool companies across Lapland to revitalise local wool use (Cervantes, 2023, p. 95).

In alignment with VillaInno's mission, this research utilises raw wool sourced from local Finnish farms, as RÄisÄnen (2019) emphasises, preserving local breeds helps protect genetic diversity, a crucial aspect of resilient ecosystems (p. 262). UNESCO and FAO have also underscored the significance of safeguarding traditional livestock breeds, citing their contributions to ecological, social, cultural, and ethical sustainability (FAO, 1997; UNESCO, 2003, as mentioned in RÄisÄnen, 2019, p. 261).

From a material science perspective, wool is inherently biodegradable due to its protein-based composition—keratin—which microorganisms can break down into natural elements (Cardamone, 2001). Research shows that wool textiles can begin to decompose within four weeks of being buried in soil (Arshad & Mujahid, 2011), although the rate depends on factors such as processing methods, soil type, and climate conditions. In contrast, synthetic fibres like polyester can take over 50 years to degrade (Webb et al., 2013, p. 3).

Another aspect worth noting is a common defect found in Finnsheep known as 'frizzy wool', which refers to extremely tightly curled wool staples that press against the skin (RÄisÄnen, 2019, p. 266). The condition is often linked to poor crossbreeding practices and reflects suboptimal feeding and care, resulting in lower wool production (RÄisÄnen, 2019, p. 266). However, the material requirements for this research are quite different from traditional textile applications. High-quality wool is not necessary—in fact, using defect wool aligns with the project's sustainability goals by diverting it from disposal and repurposing it in meaningful, creative ways.

Learning about this information struck a personal chord with me and became a turning point in my research. I felt a strong sense of responsibility—and opportunity—to repurpose discarded wool as a growing medium for mycelium. The

decision wasn't just practical or experimental; it was also symbolic. It allowed me to explore the intersection between tradition and innovation, while contributing, even in a small way, to a more sustainable and respectful use of resources.

Eventually, in the beginning of this research, there were few, if any, existing studies or precedent projects using this combination. However, this landscape is beginning to change. One pioneering effort is the BioKnit project, which explores integrating 3D-knitted textiles with MBCs, addressing geometric limitations of MBCs and their scalability in architectural design (Kaiser et al., 2021, p.10). The Living Room prototype by Newcastle University used locally sourced waste materials—including Herdwick wool, sawdust, and paper mill waste—combined with mycelium spawns. HBBE (n.d.) notes that the structure demonstrates how soft, compostable architecture can support sustainable construction while benefiting regional economies and reducing environmental impact.

In fashion, Rapagnani et al. (2024) experimented with growing sneaker components using mycelium and fibrous substrates. However, their beginning experiment suggests that wool presents specific technical challenges; its dense, animal-based fibres are not easily broken down by fungal hyphae, resulting in fragile, less stable outcomes compared to plant-based fibres (p. 1).

These three contemporary projects—BioKnit, The Living Room, and Rapagnani's experimental footwear—illustrate both the potential and limitations of combining mycelium with textile fibre like wool. Their findings have been instrumental in informing my own research, offering valuable benchmarks and inspiration as I continue to explore both of these materials in my research.

2.3. Material Driven Design (MDD)

Reflecting on my background as an architect, the typical design process often follows a similar approach. It began with zoning layout and façade concepts, and material selection came much later. In contrary, this research adopts an entirely different approach: materials selection serve as my point of departure, which reshapes how I engage with the design process, This shift introduced me to the Material Driven Design (MDD) method coins out by Karana et al. (2015), where it

involves designing from the materials as the starting point (p. 37) and facilitate designing for material experiences (p. 35).

MDD defines materials experience across four dimensions: sensorial, interpretative (meaning), affective (emotion), and performative (Karana et al., 2015, p. 37). Sensorial relates to how we physically perceive a material (e.g., if it's hard, soft, smooth, shiny); interpretative involves the associations we assign to it (e.g., classic, warm, modern); affective refers to the emotions it evokes (e.g., comforting, unsettling); and performative acknowledges the active role of materials in shaping our actions and interactions (Karana et al., 2015. p. 37).

The MDD framework encourages designers to form deep, personal relationships with materials—not only for what it is, but also for what it does (Manzini, 1986), what it expresses to us, what it elicits from us (Karana et al., 2013), and what it makes us do (Giaccardi & Karana, 2015, p. 37). In this study, materials are not passive nor chosen; they serve as an active participant and provoke responses from the designer. This relational engagement contributes to shaping design outcomes.

Karana (2015) explain that this approach will expect the designer to become fluent in their material's properties, behaviours, and production methods (p. 39). Larsen (2022), who used the MDD method in her seaweed biobased research, highlights that even what is initially perceived as a weakness in a material can become a point of creative strength (p. 12). However, she also recognises that MDD has some drawbacks, that misusing or underdeveloping a material can reduce the quality and value of a project (Larsen, 2022, p. 14). Similarly, Bak-Andersen (2018) emphasises the importance of respecting a material's limitations to ensure its meaningful application (p. 14).

The MDD method consists of four main phases in a sequential manner: (1) Understanding the Material, (2) Creating Materials Experience Vision, (3) Manifesting Materials Experience Patterns, and (4) Designing Material/Product Concepts (Karana et al, 2015, p. 41). To maintain the focus of this research, I will apply the first step: Understanding or tinkering with the Material. This particular phase involves both technical and experiential exploration, using a set of guiding questions developed by Karana et al (2015, p. 41).

Table 1

Technical characterisation set of questions [Karana et al., 2015, p. 41]

Technical characterisation
1. What are the main technical properties of the material? 2. What are the constraints/opportunities of the material? 3. What are the most convenient manufacturing processes to form the material? 4. What about other manufacturing processes? How does the material behave when subjected to other processes?

Table 2

Experiential characterisation set of questions [Karana et al., 2015, p. 42]

Experiential characterisation
1. What are the unique sensorial qualities of the material? 2. What are the most and the least pleasing sensorial qualities of the material (according to users)? 3. Is the material associated with any other material due to its similar aesthetics? 4. How do people describe this material? What kind of meanings does it evoke? 5. Does it elicit any particular emotions—such as surprise, love, hate, fear, relaxation, etc.? 6. How do people interact and behave with the material?

In project experiments at Chapter Four, I will use that set of questions as a guide to begin my growing design journey with mycelium and wool. This process will not only generate technical knowledge but also nurture a more intuitive and reflective relationship through hands-on, tactical experience. I hope to engage a dialogue that informs design decisions in a way that is analytical, sensorial and reflective.

2.4. Posthumanism and Bioethics Thinking

There are many layers of active agency in this research: wool as an animal byproduct, mycelium as a living microorganism, and the human as designer and facilitator. All of this living—or used to live—creates a kinship and entanglement in crafting the experiments. Thus, it will be redundant if I only observe through technical capabilities; instead, I am intrigued to reflect philosophically as well. This research tries to seek material as its own agency, as a living being that also has its autonomy—this challenges human understanding to share responsibility and authorship with collaborators other than humans.

Tsing (2015) frames this type of relationship through the concept of 'contamination as collaboration', that we are affected by our encounters, in a way that we affect others too (p. 27). This reciprocal relationship echoes Haraway's (2016) notion that "ontologically heterogeneous partners become who and what they are in relational material-semiotic worlding" (p. 13). She elaborates that nature, culture, subjects, and objects do not pre-exist independently; they emerge through their entangled relations (Haraway, 2016, p. 13). To 'stay with the trouble', as Haraway argues, involves making odd kin in unexpected collaborations (p. 4). Working with living or once-living materials alters designers, often in an unfathomable way, and vice versa.

The entanglement between human and non-human is often highlighted in the posthumanism theory, which critiques the legacy of humanism, as Abbagnano (1967) defines, recognises the value or dignity of man and makes him the measure of things (p. 69). In other words, it puts humans at the top of the hierarchy of life and presumes downplaying non-humans as a passive background or resources to be exploited.

In contrast, posthumanism reacts to the power imbalance, to question the myth of the human as the centre of the universe (Nayar, 2014, p. 11) and calls for a more inclusive definition of life, and a greater moral-ethical response, and responsibility, to non-human life forms (Nayar, 2014, p. 8). Simply put, posthumanism advocates treating humans and other living creatures equally. Donna Haraway (1991) also

echoes this view by emphasising that culture—which represents humans' collective evolution—does not dominate nature, nor is nature an enemy (Haraway, 1991, p. 10). Instead, all evolution and human development are processes of 'becoming-with' in Haraway's memorable phrasing in *When Species Meet* (Haraway, 2008, as cited in Nayar, 2014, p. 5).

In design, this posthumanism perspective, also known as 'More-than-human' design, pushes designers to consider the entire globe as a stakeholder, emphasising feedback loops and interactions in large systems (Forlano, 2017, p. 19). The planet will bear the consequences of our design outcomes—whether sustainable or harmful. Co-designing with living organisms, for example, offers a dialogue with natural systems—its rhythms and limitations, that in a strange way, as Tsing (2015) portrays, seems to contradict the humans' dominant hope of modernity and progress (p. 20). Over and over, we learn that humans are different from the rest of the 'living' because we look forward, while other species live day to day (Tsing, 2015, p. 20).

Humans are pressured to constantly innovate, solve and act 'now', shifting our modern perception of time—defined by urgency, productivity, and a future promised by progress. As Puig de la Bellacasa (2017) argues, making time for care time might disrupt the 'imaginings of technology' (p. 177) or, I might say, slowing down our idealistic dependence on progress. This sense of urgency diminishes our capacity to act meaningfully in the present, putting today's actions to an always-fearful uncertainty of an uncertain tomorrow. Under this logic, design no longer serves as a process *of* 'becoming-with' (Haraway, 2008, p. 1), but instead becomes a race against time. This time-driven mindset leaves little room for slowness, reflection, and taking care of the other beings and ecosystems in a genuine, meaningful way.

Despite this pessimistic critique, Puig de la Bellacasa (2017) offers a compelling perspective: exploring the temporality of care offers an inquiry into different modes of 'making time' by focusing on lived experiences rather than abstract futures (p. 177). As well, Rodrigues asserts, taking care is a powerful way of learning... You can only learn if you are there, if you show up for this other living being. (Lusia, as cited in Ostendorf-Rodríguez, 2023, p. 30).

A supplementary guidance that could help us to implement a harmonious way in co-designing with living matters is a matter of respect and balance. Inspired by Kimmerer's concept of ‘Honourable Harvest’ that is cited in Ostendorf-Rodríguez (2023), it discusses a protocol for ethical giving and taking (p. 23), what is enough, what is respectful, and what can be given back. Mathews (2016), for instance, proposes a bio-inclusive ethic*,* urging us to act as environmental stewards rather than masters, guided by bio-proportionality—a principle of maintaining balance within ecological systems (p. 15). Starting with an acknowledgement of the prima facie entitlement of all living things to their own existence, a commitment to avoid harming living things would follow (Mathews, 2016, p. 15).

This philosophical grounding is not separate from policy—it shapes how I plan to interpret and embody ethical guidelines in practice. The European Commission’s Ethics for Researchers (2013) outlines twelve golden rules to guide responsible research (p. 24). I anticipate that it will align closely with several of these principles: the do no harm principle (Rule 2), respect for animal welfare (Rule 5), the application of the 3Rs—Replacement, Reduction, and Refinement (Rule 6), proportionality (Rule 7), and biodiversity protection (Rule 11). As the project progresses, these rules will serve as ethical reference points. Their relevance and applicability will be assessed continually through material choices, sourcing practices, and collaborative processes, ensuring the research remains aligned to both ecological and ethical concerns.

The wool is classified as an Animal By-Product (ABP) Category 3 under Regulation (EC) No 1774/2002 (European Parliament & Council, 2002). I plan to source wool ethically through small farms or enterprises connected to the Villainno network. As Nikula & Kelloniemi (2023) report, Finnish wool is traceable, produced in stress-free environments, and contributes to local biodiversity (p. 30)—meeting the criteria outlined in Rules 2, 5, and 11.

The mycelium will be cultivated using this wool as an organic waste substrate, offering a sustainable alternative to synthetic materials. Spawn can be purchased from local mushroom farms in small quantities (typically 50–100 grams), which is sufficient for the scale of this experiment. Another option is to collaborate with fellow artists or designers who work with mycelium and may have leftover spawn to share. If I have any surplus from my own experiments, I intend to offer it to others—

designers, artists, or researchers interested in working with mycelium. This practice of intentional sharing aligns with the principle of proportionality (Rule 7), encouraging mindful consumption and reducing waste by buying only what is needed and redistributing what remains.

Together, the integration of mycelium and wool in this research tries to implement a careful, ethics-driven approach to material design, ensuring that both living and once-living materials are used responsibly and respectfully.

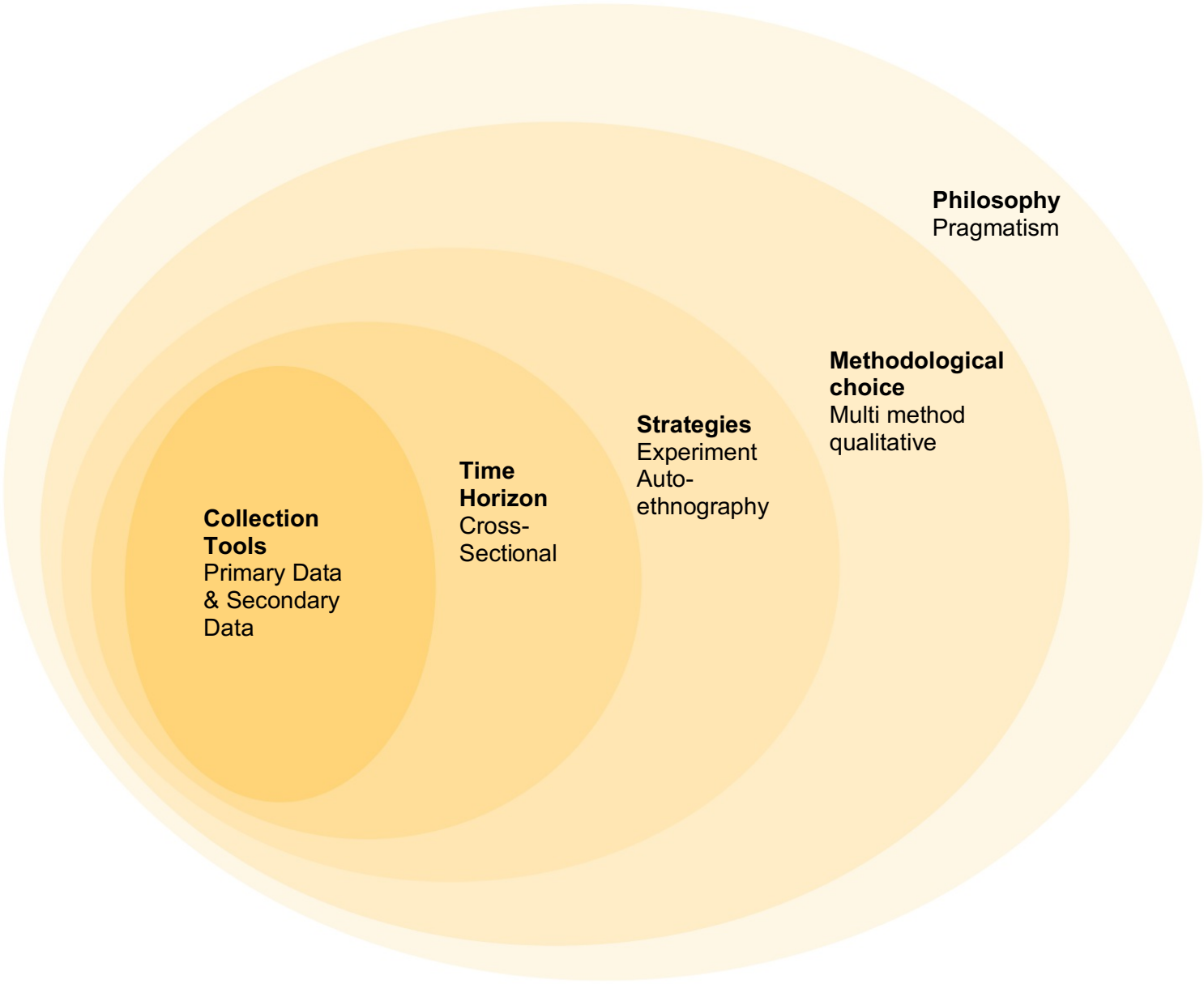
3. Methodology

Designing an appropriate methodology for this experimental journey is essential, particularly as the field of growing design remains relatively new. As this research is interdisciplinary—merging artistic and scientific approaches—it still lacks a widely accepted framework. As Vijayakumar et al. (2024) point out, these fields lack shared definitions, tools, and methodologies, and most likely related to the fact that these fields are still in their infancy (Pollini, 2024, p. 3). Thus, in this chapter, I intend to break down which research design and approach are suitable to examine this research further, explain the data collection process, the strategy for data analysis, and consider the ethical dimensions of the research.

3.1. Research Design and Approach

Figure 2

Research design inspired by Saunders, Lewis and Thornhill (2011)



Based on the research design onion by Saunders et al, this research will be defined by several aspects: research philosophy, methodological choice, strategies, time horizon, and data collection tools (Figure 2).

This study will employ a pragmatic approach, focusing on practical outcomes, specifically in exploring sustainable materials through hands-on experiments. As Saunders et al. (2019) note, a pragmatic approach is a value-driven research, often based on the researcher's own doubts and beliefs, making reflexive thinking also an integral part of the process (p. 147). Additionally, it is easily conceived as a philosophical stance for doing instead of a theory per se (Clarke & Visser, 2018, as cited in Dube, 2024, p. 1001).

In experimenting with mycelium and wool, I am not merely applying theory, but actively testing out what works best; what type of wool works to grow mycelium (e.g. the one with more animal fat), what kind of environment (temperature, humidity), which technique considered more efficient to use, and whether additional material need to be added in the mixture. Dube et al. (2014) suggest that selecting a particular guiding method is recommended for delivering the experiments (p. 1001). In this case, I comply with MDD as a practical guiding method to observe the technical and experiential characterisation of the materials.

The methodological choice for this research is a multi-method qualitative, specifically, more than one qualitative method is integrated without any quantitative techniques. Under the appropriate conditions, multiple qualitative methods can prove very useful toward gaining a more fully developed complexity and meaning in the researcher's understanding of a subject matter (Denzin & Lincoln, 2011; Flick, 2007, as cited in Research Design Review, 2021). Many scholars believe this approach to enrich the study as one method will help another. It can provide a more complete picture of the issue or phenomenon under investigation (Research Design Review, 2021).

As one of the components of a multi-method approach, initially, I intended to use Art-Based Action Research (ABAR). I saw mycelium not just as material, but as a community—a collaborator and participant in the design process. Also, a plan to engage the public through exhibitions serves as another form of community sense.

However, as these experiments evolve, shaped by failure, adaptation, and the material's own agency, it became clear that autoethnography will be the best approach.

Autoethnography, in this context, serves as a method rooted in a first-person perspective—where the researcher is also the subject. This aligns with care practices in design research (Tekogul & Forlano, 2024), and broader first-person methodologies (Varela & Shear, 1999; Tomico et al., 2012). It resonates with the nature of this research, which involves a learning by doing process—engaging in hands-on experimentation informed and inspired by the work of other artists and researchers, while also learning from the living materials themselves as active contributors. This method enables the researcher to capture what Jones (2013, as cited in Pollini, 2024, p. 4) calls the 'granular experience of the everyday', valuing emotional and sensory layers that emerge through repeated daily interactions.

Bochner describes autoethnography as 'the genre of doubt'—it allows scholars to maintain an emotional and personal connection with their research (Pollini, 2024, p. 4) and acknowledges it as a source of insight, instead of flaws or invalid data. This method often requires self-observation and self-reflection in the process (Pollini, 2024, p. 4). Recently, it has been adopted to explore the complex entanglements of perceiving the non-human entities (Ofer & Alistar, 2023, *Introduction* section), or the cohabitation in multispecies contexts (Tomico et al., 2023, p. 30)—areas that are difficult to assess through traditional methods.

Throughout this research journey, data collection followed a cross-sectional time horizon—gathered within a specific time frame without tracking long-term changes. The hands-on material experiments took place over five months (March to August 2024) during my internship and visiting researcher period in Helsinki. This phase provided foundational, tacit knowledge through direct engagement with living materials. It was followed by a five-month academic exchange in Copenhagen (September 2024–January 2025), where the focus shifted from practical experimentation to theoretical inquiry. There, I explored the cultural, ethical, ecological, and aesthetic dimensions of materiality—bridging practice with critical theory. In the final exhibition (February–March 2025), public responses were gathered to understand not only how the work was interpreted, but also the reflection, ethical questions and future possibilities it raised.

3.2. Data Collection and Methods

Figure 3

Data Collection [Arrafiani, 2025]

In collecting the data, I will use both the primary data (e.g., field notes and photographs, videos from the experiments, surveys) as well as secondary data (e.g., weekly journal, report and reflective essay).

Primary data, like field notes, is the central method to capture the development of day-to-day hands-on material experiments. At times when materials exhibited unexpected behaviours, field notes were beneficial as the main recording tools, helping to trace emergent patterns or spontaneous decisions made during those times.

Other primary data, such as photographs and videos, will be used to document the experimental process. Pink (2007) describes photographs as ‘visual texts’ (p. 21), emphasising their value in practice-led research for surfacing non-verbal insights and supporting later analysis. By all means, through artistic intuition in the visual documentary**,** the research process itself becomes a means of performative expression rather than merely a documentation of outcomes. This aligns with Jokela & Huhmarniemi (2018), who state that art can also be the subject of development or the tool for the research’s data collection and analysis (p. 9). Next, a survey-based method will be conducted during the exhibition in Arktikum, which aims to capture public perception and interpretive responses to the materials, ecological and ethical messages.

Secondary data, such as a weekly journal, will be made to trace the evolving kinship between the designer and the bio-living partners—documenting surprise moments, failure, and adaptation. It will contain a series of collective field notes, sketches, and photographs, along with weekly reflection (for example, what technique worked, and how to make it better next time). As aligns with Schön’s (1983) concept of ‘reflection-in-action’ (p. 68), it emphasises learning that occurs through personal engagement and iterative feedback.

In the beginning, the internship report will be a mandatory task to be submitted to the university and will be separated from this research. However, since my internship’s task aligns with these experiments, I will incorporate insights from this report—particularly descriptions of my work environment and technical knowledge. In an academic exchange at the University of Copenhagen, I will write a free-form

reflective essay as part of the course *Rocks, Fields, Seas, and Forests: Aesthetic and Cultural Engagements with Materiality during the Climate Crisis*. I will take this opportunity to combine my practical artistic expression with a reflective writing essay, drawing theories from the literature, mainly in posthumanist critical theories.

3.3. Analysis Method

The data gathered throughout this study will be analysed through thematic analysis, a qualitative method well-suited to the interpretive and reflective nature of this study. Thematic analysis allows for the identification of similar emerging patterns and meaning across diverse types of data. It is widely used for identifying, analysing, and interpreting patterns of meaning or themes within data (Braun & Clarke, 2006, p. 6). The process will begin with re-reading journal entries, reviewing photographs, reading public responses and analysing the reflective essay. Consequently, I will identify repeated patterns and then organise them into three specific themes: Sustainable Materials, the Practice of Care and Ethical Consideration.

The first theme, sustainable materials, reflects on the ecological potential of alternative material practices. This includes examining if the process behind the experiments remains sustainable (e.g., water utilisation, use of non-toxic chemicals, waste and disposal, non-extractive organisms, and so on). The second theme, the practice of care, comes into being through my daily interactions with the materials. This care was not only technical—such as maintaining the proper temperature or humidity for mycelial growth—but also emotional, where care becomes both method and meaning. This particular theme is not only data-driven but also theory-driven, influenced by post-humanist thought.

The final theme, ethical consideration, emerges from my reflections as a designer, as well as feedback gathered from participants during the exhibiton. Engaging with living organisms raised critical questions about authorship, agency, and responsibility. This led me to confront the complexities of collaborating with nonhuman agents and to consider the ethical implications of presenting such work in public. Rather than offering definite answers, this theme invites openness to

ambiguity, to doubt, and to the evolving ethics of working within entangled multispecies.

3.4. Research Ethics

To avoid confusion, this section outlines the general ethical framework guiding this research, while specific bioethical concerns related to living materials were addressed separately.

In every process throughout this research, I try to uphold ethical responsibility with care and transparency. Following an ethical framework by SATORI Project (2017), all information will be collected with voluntary consent, to ensure the security of personal data, and minimise the use of animals in experiments. Similarly, Muratovski (2016) noted that data must be securely stored to prevent unauthorised access (p. 76). He added that while selected data may be shared with qualified researchers for academic verification, it will never be disclosed publicly without consent (Muratovski, 2016, p. 76).

In activities that include public engagement—such as focus groups and surveys during the Arktikum exhibition—I will clearly communicate the purpose of the research and secure consent. Focus group participants will sign physical consent forms, while digital surveys will include a checkbox confirming their agreement for data to be used for academic purposes.

Another supplementary ethics that I follow is a Non-Disclosure Agreement (NDA) with the studio where I will conduct my internship, to ensure no specific material recipes and internal methods are publicly accessible. Even if necessary, it can only be accessed by the supervisor or examiner of this thesis. Regardless, any information I provide in this thesis will be based on open-access knowledge or personal observation and findings, ensuring that no sensitive or proprietary information is included.

4. Living Wool: A Research Project

This chapter moves from methodology to the actual making—observing the spaces, undergoing the experiments, and engaging in public forums. The project unfolded over eleven months across three main settings. It began with an internship at Caracara Collective (March–May 2024), a visiting researcher period at Biomaker Space (June–August 2024), and an academic exchange at the University of Copenhagen (September 2024–January 2025). The final destination, an exhibition at Arktikum (February–March 2025), offered a space to share what I had learned—and unlearned—throughout the whole process.

At the core of this project lies an ongoing inquiry about how the exploration of mycelium and wool might function as sustainable, bio-based materials. Each stage offered a different entry point into that curiosity, an ‘aha’ moment—from technical skills and lab routines to more subtle shifts in mindset—as relationships with the materials evolved and entangled time to time.

To keep the clarity and focus, this chapter will be divided into three sections. The first will disclose the workspace settings—what studio or lab made it possible or limited to conduct this type of project. The second describes the key experiments—the actual process—how to, what worked, what failed, how the materials developed, and what I learned. The third reflects on the Arktikum exhibition as a moment of pause: not only an opportunity to share, but also to listen to how other people interpreted the work and what questions it raised. Each part will be equipped with visual documentation, and where helpful, tables will be utilised to summarise outcomes. Each result in this chapter will be further examined through a thematic analysis in Chapter 5.

4.1. Workspace Setting

Co-designing with living matter naturally involves an unconventional kind of work setting. This wasn’t a typical design process, nor was it something that could unfold in just any studio, at least that was what I thought. Throughout this project, I became familiar with three different workspaces, at Caracara Collective, Biomaker Space and Biofilia—each with its own possibilities and limitations. In this section, I’ll describe

how these spaces shaped the way I worked and what I was able to learn from each of them. I learned to observe not just the materials, but to the rooms they inhabited and the tools they made visible.

When I first came up with the idea for this research, I remember feeling quietly overwhelmed. I was unsure where to begin. The word ‘bio’ carried a weight and sounded intimidating, especially since I had no formal background in biology. Coming from an architecture background, I was used to thinking in terms of structure and functionality, with a tendency to move quickly into making. My first concern wasn’t whether the idea was valid, but rather: Where could I even begin to grow something like this? I imagined a clean laboratory, full of high-tech equipment I didn’t know how to use, and researchers in white coats. That image didn’t last long.

The first step took me to Caracara Collective**,** a studio in Helsinki run by two designers—Aleksi Vesaluoma and Aleksi Puustinen—whose work focuses on turning biowaste into usable materials and products. I had seen their previous projects involving mycelium and reached out with interest. They welcomed me as an intern from March to May 2024, and this turned out to be a key starting point for the whole project.

My daily tasks included helping with their bio-based product—working with biowaste and biomaterials, from orange peels, discarded Christmas trees, to SCOBY leather making. But more importantly, they supported me in running my own experiments with wool, even provided me with the leftover mycelium spawns they had on hand. It was at Caracara that I first learned the basics of handling living materials: how to keep a sterile space, how to prepare a substrate, what kind of tools to use, and how to observe the slow and subtle signs of growth.

The studio is an industrial maker, mainly a workshop, equipped with tools like a shredder, mixer, hydraulic press, oven, sanding machine and a material crusher. The space for working with mycelium, however, was modest—set apart in a quiet corner to preserve sterility. Its simplicity was humbling, a simple setup: a sink, pressure cooker, large working table, grow cabinet fitted with a humidifier and indirect light, dark chamber with temperature and humidity controller—nothing you couldn’t find at a garden centre or adapt from a kitchen. This was not the laboratory I imagined; it was better: unscary and more ‘forgiving’, exactly the kind of space I needed to begin.

Figure 4

Mycelium workspace corner at Caracara Collective as observed during internship; current setup may differ [Arrafiani, 2025]

Notes

1. Dark / incubation chamber
2. Humidifier
3. Large working table
4. Pressure cooker
5. Sink
6. Fridge
7. Fruiting/ growing/ transparent cabinet

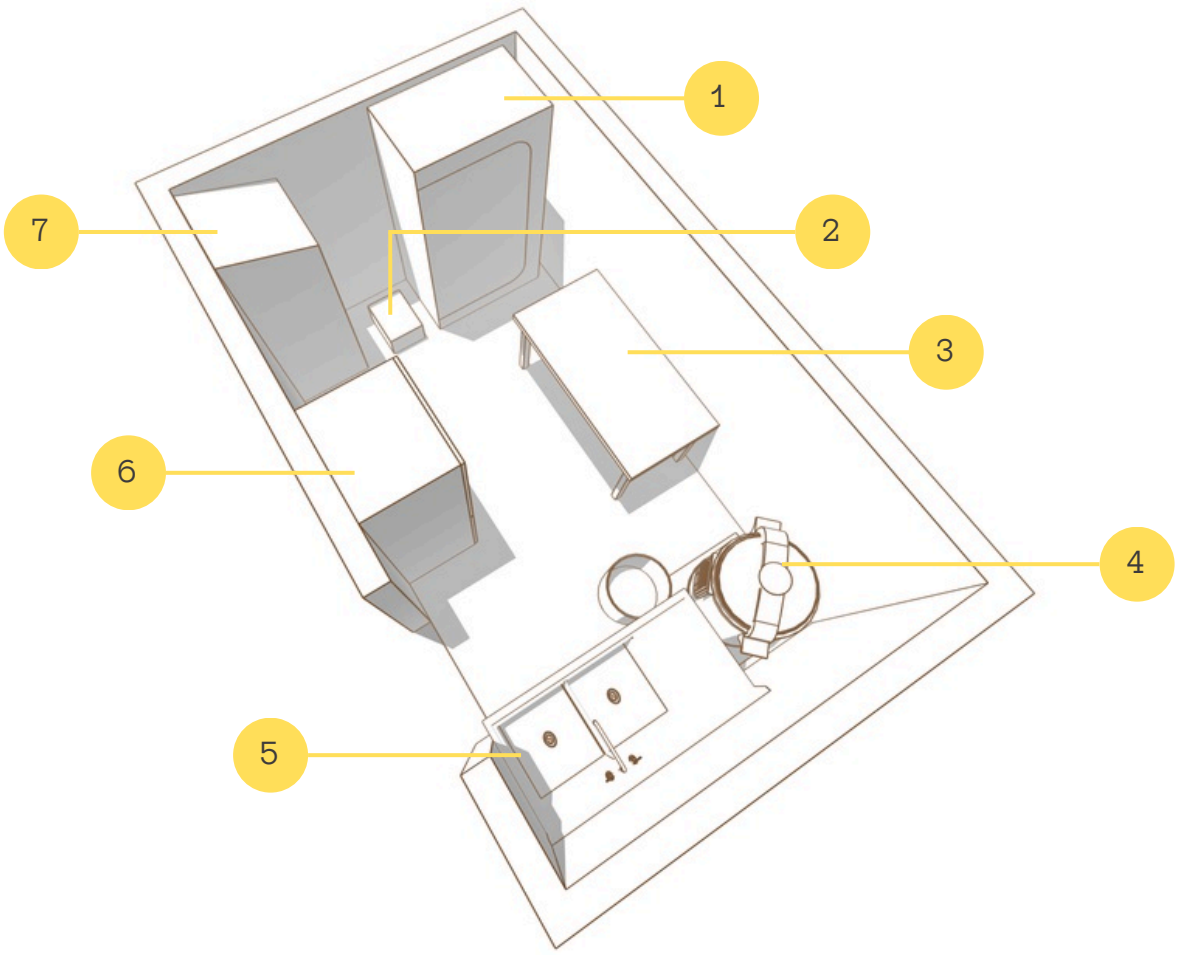


Figure 5

Tools and Equipment for Mycelium Work at Caracara Collective [Arrafiani, 2024]

My second stop was the Biomaker Space, a research-led maker space housed within Aalto University and coordinated by Ena Naito, a doctoral researcher and designer**.** I joined as a visiting researcher for around two months, from June 19 to August 31, 2024, with a focus on the material development of mycelium and SCOBY. Unlike my previous internship, where tasks were primarily assigned, this setting allowed for a more autonomous approach. I was responsible for designing my research plan, shaping my practice into a more structured habit—planning what I want to do, learning to prepare a schedule, and writing weekly reflections.

When I started, three other researchers were working on parallel projects—ranging from SCOBY-based materials, natural dyeing techniques, to slime mould and spirulina cultures. The space exists to support low-threshold experimentation for students, designers, and community members working on bio-themed projects. What stood out to me was not only the openness of the space, but the way it invited a shared co-existence—not just among humans, but also across species. We are also encouraged to participate in regular peer meetings. This session, often informal but constructive, is a place where we share our development and exchange feedback.

The Biomaker Space was initiated in response to a common gap faced by many art and design students: the moment they graduate, they often lose access to university workshops and tools (Naito, personal communication, June 19, 2024). This space was built to give a framework to support emerging designers in creating their own garage lab. In this flexible, low-tech, yet functional space, creativity could continue to grow independently. This opens a new layer of perspective, that bio-art, which often links to professional and scientific fields, is now shifting to a bottom-up initiative. In many ways, it reflects the broader spirit of the DIY-bio movement, which has brought biological experimentation into the hands of ‘citizen biologists’ or ‘biohackers’ (Erikainen, 2022, p. 288). It has often been referred to as the amateur garage, basement, and kitchen science (Naito, 2023, p. 12).

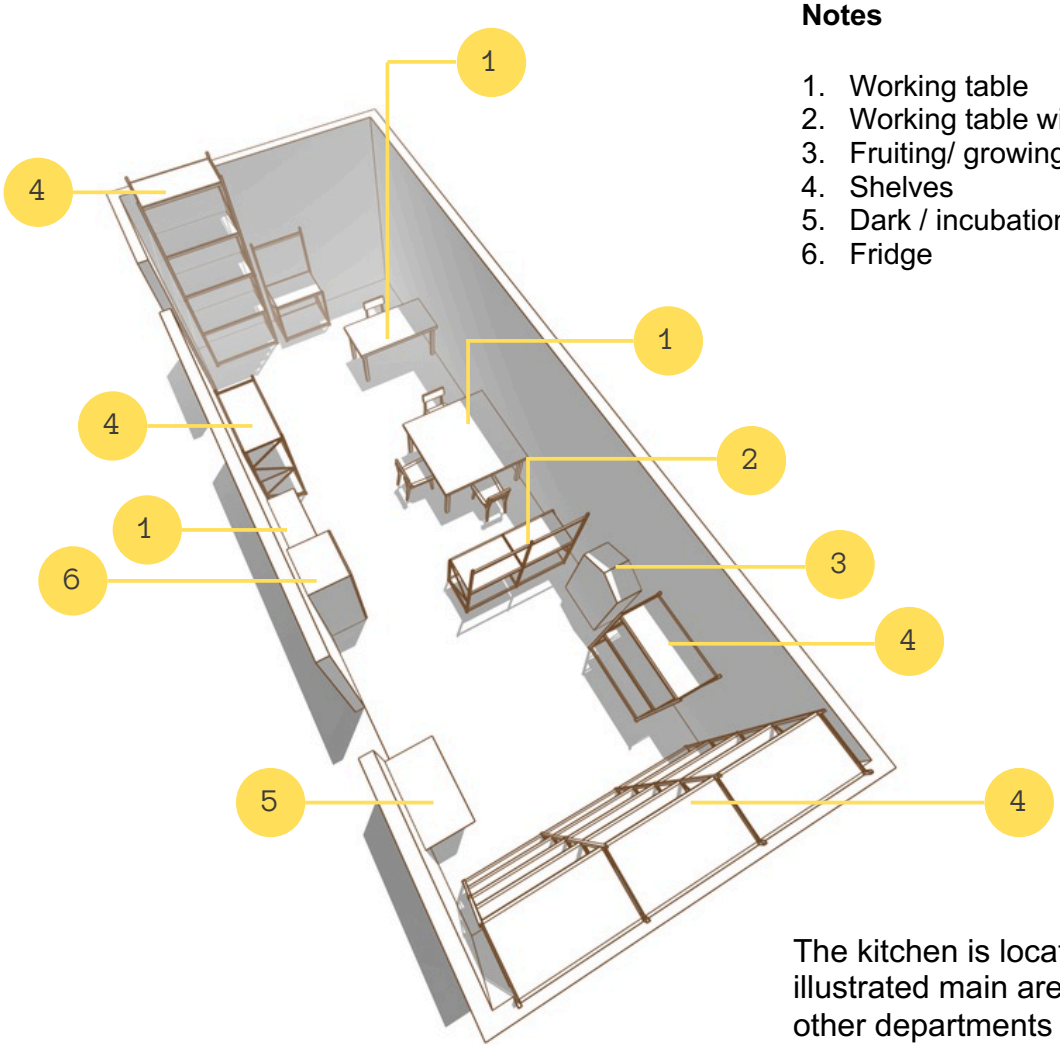
The tools and equipment I used at Biomaker Space were considerably more modest than those at Caracara. Initially, I relied on basic kitchen tools: a stove, a sink, cooking pots, and a DIY incubator made from a polystyrene box—easily sourced from a local shop and adjusted with a simple temperature gauge. As this space was having largely support from the community, I got connected with a fellow mycelium

researcher, who generously lent me essential tools: a Still Sir Box (SAB) for maintaining sterility during inoculation, a heat mat to stabilise room temperature, and even shared leftover mycelium substrate from her experiments.

One of the key challenges was the absence of a dedicated sterile zone for working with mycelium. Since the space is open to accommodate a variety of biological practices—not limited to one organism—sterility had to be improvised. Each inoculation required careful workarounds to keep the process as clean as possible, using what was available.

This experience shifted my perspective entirely in experimenting with living agency. It made me realise that even my own kitchen can be enough to begin, and with the support of a like-minded community, the space surprisingly grows to a different space of making: collective, grounded, flexible and vibrant.

Figure 6
Layout of Biomaker Space. Layout, tools, and equipment may differ from the time of my visit [Arrafiani, 2025]



Notes

1. Working table
2. Working table with attached racks
3. Fruiting/ growing/ transparent cabinet
4. Shelves
5. Dark / incubation chamber
6. Fridge

The kitchen is located apart from the illustrated main area and is shared with other departments within Aalto Studio.

Figure 7
Workspace at Biomaker space [Aalto studio, 2025 and Arrafiani, 2024]

My third encounter brought me into a more formal laboratory setting: Biofilia, Aalto University's bio-art lab. When I expressed an interest in cultivating mycelium from wild mushroom spores, Naito kindly connected me with the manager of the lab. This was where I first experimented with inoculation using mushroom spores I harvested from the forests of Äkäslompolo and the coastal woods of Otaranta. My time in the lab was brief—just two days—so I cannot speak to the whole dynamics of the workspace. Unlike the previous studios, Biofilia is specifically equipped for biological research and creative experimentation—providing access to tools used in molecular biology, tissue culture, and microbiology (Aalto University, 2025). From what I observed, it was the only environment I entered with controlled sterile protocols and specialised instruments designed for more precision work with microorganisms.

In contrast to the DIY settings I had grown used to, Biofilia felt closer to the kind of laboratory I had once imagined when this journey began: clean, regulated, and scientifically focused. It offered conditions suitable for more advanced bio-based projects, particularly those requiring higher sterility. While I was only there for a moment, the experience gave me a glimpse of what's possible when experimentation meets infrastructure.

Figure 8

Biofilia [Aalto.fi, 2025 and Arrafiani, 2024]

Comparing the workspace settings

Each of these three spaces offered a different workstyle—from the more private designer's lab, the improvisational warmth of a community studio, to the relatively scientific lab. Together, they shaped not only how I worked but also how I thought about access, scale, and the ethics of making within the community. To clarify these contrasts, I've created a comparative table of the three settings on the next page.

Table 3

Comparative Overview of the Three Workspaces [Arrafiani, 2025]

Bio-lab	User	Mycelium space setting	Tools & Equipment Used	Purpose
Caracara Collective	Private studio, open for collaborative work, limited public access	Dedicated space and tools for mycelium	Basic & DIY setup	Small–medium scale products or objects
Biomaker Space (Aalto University)	Bio coworking, community-based, more open access	No dedicated mycelium space	Basic & DIY tools, open to more advanced tools depending on grants	Small scale; can link to Aalto facilities for larger/complex processes
Biofilia (Aalto University)	University-based, limited access, for art–science projects	Space dedicated to sterile work	Broader set of biology-related equipment	Suitable for larger or more advanced projects than Caracara & Biomaker Space

4.2. Mycelium and Wool Material Experiments

This section marks the heart of my research—producing the artistic expression of the living materials. The next question in my head was: What tools do I need to start going? In this section, I will introduce the basic starter guide on what to prepare and give a general overview of how the typical process will unfold. This step-by-step action guide (see Figure 10) came from my own experience—from a beginner's point of view—and something I learned along the way.

A Starter Guide

Designers rarely begin their work with fungi taken directly from the wild. Instead, they typically use mycelium in the form of spawn**,** which has already been prepared on a carrier, such as grain or sawdust. This spawn then serves as the starting material for inoculation into another substrate, allowing for more controlled growth and reproducible results.

Although mycelium can grow freely in the wild, bringing it into a controlled lab environment requires a different set of conditions. In nature, fungi adaptively respond to threats and changes by producing a wide range of enzymes to defend their territory; however, in sterile lab settings, this diversity of stimuli disappears—causing the fungi to ‘let down their guard’, which ironically makes them more vulnerable to contamination (Mc Coy, 2016, p. 205). Thus, in domesticating mycelium in an artificial environment, it needs sterile protection, especially during the early inoculation phase (see Figure 10) when it's most vulnerable.

For all its worth, the inoculation stage demands strict cleanliness: masks should be worn, talking kept to a minimum, and all direct tools—such as gloves, trays, knives, and weighing scales—must be sterilised with 70% alcohol. Even phones and cameras should be wiped down if used during the process. At Caracara, where mycelium work had a dedicated space, I only needed to sterilise a specific corner of the room—an approach I found both practical and comforting. In open or shared

spaces where a sterile room is not feasible, an SAB (see Figure 9) can be an alternative for maintaining a clean micro-environment during inoculation.

Figure 9

List of Tools and Equipment [Arrafiani, 2025]

1. Autoclave/Pressure cooker/cooking pot
2. incubation tent/box
3. Sieve
4. Tray/boxes
5. Kitchen scales
6. Thermostat/thermometer
7. Hygrometer
8. Humidifier
9. The Still air box (SAB)
10. Drying/growing tent
11. Seedling heatmap/heat lamp
12. Gloves
13. Alcohol 70%
14. Spray bottles
15. Hand sanitiser
16. Tissue/cloth
17. Tap measure
18. Scissor & knife
19. Dedicated brush
20. Food wrap
21. Mask
22. Tape
23. Fridge
24. Stove

Moving ahead, for this experiment, I used raw wool (or greasy wool), unprocessed directly after shearing. Following advice from my internship mentor, I sterilised the wool by boiling it in hot water for around an hour—an intuitive process, with no fixed scientific reasoning for the timing. A pressure cooker would be ideal, but for small-scale trials, a regular cooking pot worked fine. After boiling, it's soaked in cold water and drained—retaining some water is essential. Still, too much excess water could lead to contamination, as per McCoy (2016), noting that the goal is to get the material as wet as possible without creating a product that is 'muddy' (p. 203).

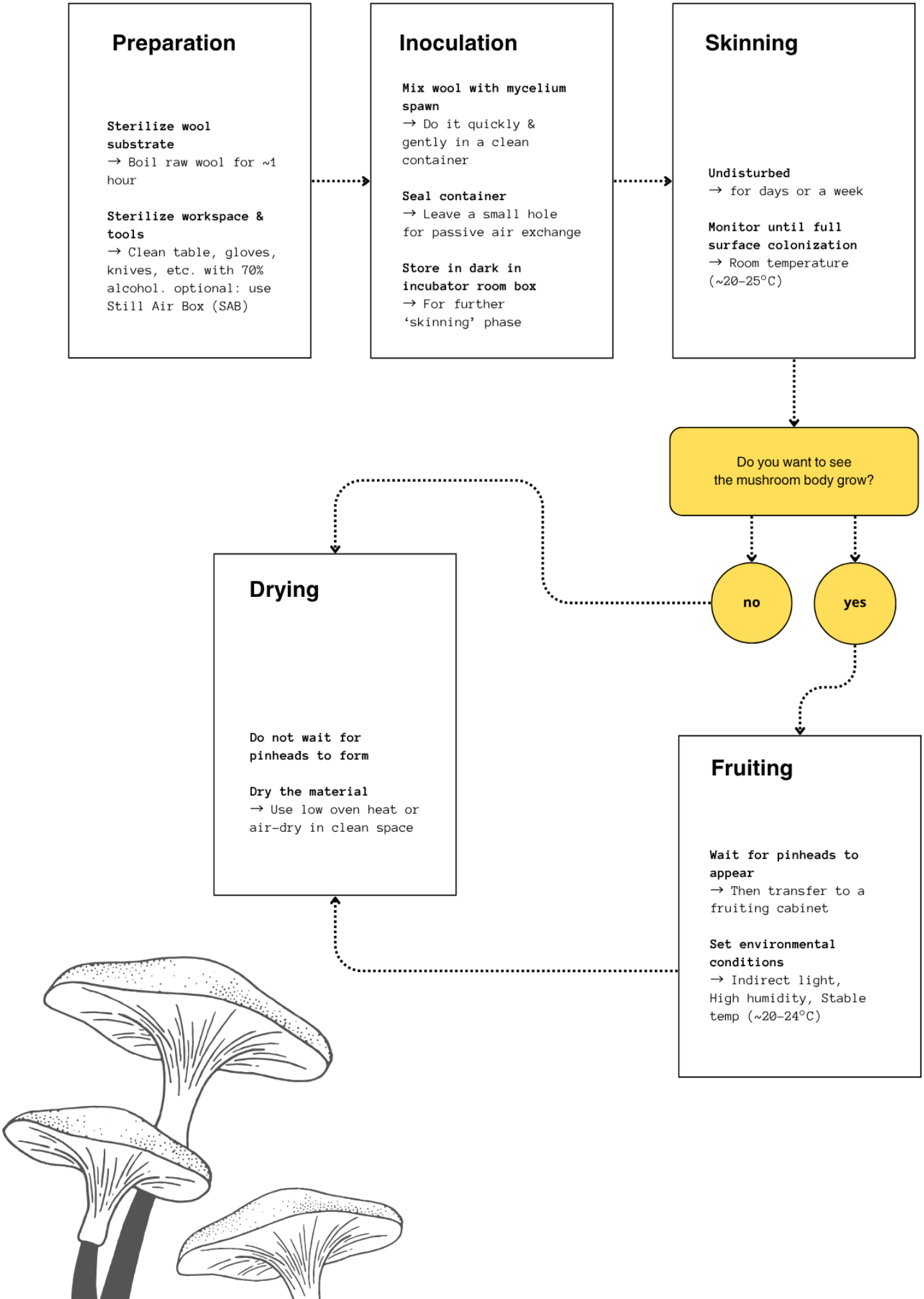
Once the wool was sterilised, it was transferred to a clean container and gently mixed with mycelium spawn. This step needed to be done quickly to reduce the mycelium's exposure to fresh air. As McCoy (2016) explains, during this early, fragile phase, fungi thrive in low-oxygen and high-CO_2 environments—mimicking the soil or decaying wood they naturally inhabit in the wild (p. 203). To recreate these conditions, the container was then sealed tightly, leaving a small hole for passive airflow (McCoy, 2016, pp. 203-204). Once secured, the container was placed in a dark space at room temperature. As McCoy notes, most cultivated mushrooms are mesophilic, meaning they grow best in temperatures similar to what humans find comfortable—around 21°C (p. 204).

In my own process, I left the container undisturbed for several days, even up to a week, monitoring only temperature and humidity. Like a newborn, the mycelium is too delicate during this stage to be moved or touched. Once early growth stabilised, I checked regularly for signs of colonisation or contamination.

The designer can decide between two directions: allowing the mycelium to grow only a surface skin (skinning phase), or letting it progress into mushroom fruiting. If only the skin is desired, the material should be dried as soon as surface growth is complete—before pinheads emerge—either with low heat in an oven or by air-drying in a clean environment. If fruiting is the goal, the material should be moved to a growing chamber as soon as pins appear, where light, humidity, and temperature can be adjusted to support continued development.

Figure 10

Mycelium Cultivation Workflow [Arrafiani, 2025]



The following pages present four artistic experiments I have conducted. Each experiment investigates both the technical and experiential characterisation of the mycelium–wool composite. To guide this exploration, I apply the MDD method developed by Elvin Karana (2015), using the set of guiding questions introduced in the theoretical framework chapter (see Tables 1 and 2). These questions help examine how the material performs, transforms, and what kinds of emotions or associations it evokes in each context.

Experiment #1 : Myco-Felting I

Figure 11

Myco-Felting I [Arrafiani, 2024]

This experimental process is documented in Appendix A.

Ingredients

65 gr raw wool (weighed when it was wet)

32 gr *Pleurotus ostreatus* (oyster) spawn

Timeline — 4 weeks

2024, April 22 — Inoculation

2024, May 9 — Maximum mycelium ‘skin’ growth & moved to bigger container

2024, May 16 — Mushroom ‘fruiting’ phase

2024, June 21 — harvesting

Temperature

20.1 ℃

Technical Characterisation of the Material

In this first experiment, I want to test whether mycelium can be grown in raw wool substrate only. I named this experiment Myco-felting because its behaviour has similarities with the principle of wet wool felting. In both cases, fibres become entangled and bonded, yet here the agent of binding was not water, but the living mycelium itself. Unlike in wet-felting, I did not need to prepare or card the raw wool; the mycelium grows on the raw fibres directly, binding them together organically.

During experimentation, it underwent noticeable changes. During boiling, the wool released a strong, burnt smell. Wet wool becomes dense and felted like a glue, making it difficult to tear apart. Initially, the wool acted as a fibrous, nutrient-rich substrate, allowing the mycelium to spread and form a dense, cotton-like network. As colonisation progressed, the material retained moisture, giving it a soft and spongy texture. Over time, as the water content decreased, the mycelium became softer but also brittle. While it successfully bonded with the wool, adding structural cohesion, the final dried form remained fragile and prone to breaking. Some pins appear in the early phase; however, due to technical challenges in retaining the humidity,

mushroom fruiting could not be fully achieved, leaving behind a material that held its shape but required further refinement to improve durability and flexibility.

Experiential Characterisation of the Material

Throughout this experiment, I was engaged in a multisensory experience: the visual, the smell, and the touch. The first thing I notice is how it reminds me of a natural landscape with its inhabitants. It is pretty interesting to observe the transformation that resembles a shifting landscape: from a cloudy, cotton-like landscape into delicate webs that look like a thread of silk. When I touch it, the surface feels soft, almost like a cloud. The smell carried the presence of earth and damp forest soil, grounding the material in a sense of aliveness that never quite disappeared, even after drying.

When thinking about the material itself, the skinning process is often treated like the endpoint, which determines it as a material. The fruiting body of a mushroom, on the other hand, feels more like a gesture or an expression. Still, I couldn't help but look for it. Watching the mushrooms appear brought me back to when I first became fascinated by them, when they started growing through the floorboards of my studio. It triggers a memory, a good feeling that reminds me of home and resilience.

The process also evoked questions about communication and relations. Mycelium in forests is often described as an underground network of exchange between plants and trees. In this experiment, with the absence of vegetation, I wondered: Does mycelium still communicate in such a context? It felt as though a new habitat had emerged, not because I designed it, but because the mycelium and wool together created conditions for another life to take shape. I found myself watching, realising that this was not just about producing a material but about witnessing a cohabitation, a living dialogue, a vessel of memory, a connection, and a call to surrender to Mother Nature.

Experiment #2 : Mycelium Felting II

Figure 12

Myco-Felting II [Arrafiani, 2024]

This experimental process is documented in Appendix B.

Ingredients:

90 gr raw wool (weighed when it was wet)

90 gr *Ganoderma lucidum* (reishi) + aspen wood + chips + oat + gypsum

Timeline	— 8 weeks
2024, June 25	— Inoculation
2024, June 27	— Mycelium ‘skinning’ phase
2024, July 3	— Full mycelium skin colonisation
2024, July 8	— Mushroom pins
2024, August 7	— Mushroom ‘fruiting’ phase, moved to a growing tent
2024, August 19	— Contamination, some part need to be removed

Temperature

21-24 ℃

Technical Characterisation of the Material

In this experiment, I introduced new agents to the growth process, working with Reishi mycelium supplied in a substrate composed of Aspen wood chips, gypsum, and oats. The aim was to compare how the mycelium behaves when colonising raw wool alone versus when supported by additional nutrient plant-based materials.

The preparation revealed immediate challenges. Mixing the substrate with raw wool proved difficult, as the Reishi substrate was dense with additional materials and resistant to breaking down into smaller fragments. This limited how evenly it could be distributed throughout the wool fibres, which in turn may have influenced the eventual growth pattern. The inoculation was carried out at 24 ℃ under controlled conditions, with moderate humidity and no direct light exposure.

Within two days, a rapid colonisation became visible. White filaments began to grow across the wool fibres, thickening and interwoven into networks. This early

acceleration was striking, since Reishi does not normally produce a visible change within such a short timeframe. The behaviour pointed clearly to the importance of the substrate: the nutritional complexity of the wood chips, gypsum, and oats acted as a catalyst for growth, amplifying speed and density.

By the eighth day, the mycelium had fully colonised the substrate and wool, producing a dense sponge-like body with a surface skin. The structure has elasticity and softness when pressed, resembling a cushion covered in a delicate but wild vegetative layer. Compared to Myco-felting I, the material felt far more robust during its living phase, showing resistance against tearing and compression. However, upon drying, the once spongy and resilient mass became brittle, fracturing under pressure. While stronger and less fragile than in the first experiment, it still lacked the flexibility and toughness required for long-term stability.

Experiential Characterisation of the Material

In a sense of sight, I feel like I enter an alien landscape, reminiscent of a lunar terrain or eroded rock surface. Layers of colour variation, from cream to faint ochre, gave the surface a geological quality, while the irregular textures suggested both organic, wild and a sense of disorder. In contrast, the first experiment (Myco-felting I) had been more uniform and tidy, producing surfaces that felt closer to a softer textile. This second attempt, however, embodied wildness: it manifested the agency of multiple ingredients simultaneously, each contributing to the overall form.

The tactile sensation was similarly performed. The surface, once colonised, became rough and fibrous, with resistance giving way to sudden breaks when pressed more firmly. It shows the dual sides of both fragility and strength. Smell remained consistent with the first trial: earthy, grounding, and reminiscent of wet soil after rain.

What intrigued me most was the sense of collaboration. The mycelium engaged in a negotiation with its partners, now with the addition of the members: the wood, the oats, and the gypsum. Each agent seemed to leave a trace: the fibrousness of wood, the density of oat, the mineral of gypsum, and the softness of wool. The Reishi radically grew tall; it feels that they are a social and adaptive organism, revealing its

ability to integrate and redistribute these characteristics into a new composite. Compared with the singular partnership of wool in the first experiment, this second attempt revealed an almost communal vitality and a collective agency.

The mushroom body itself emerged as a physical manifestation of this agency, growing tall and even provocative, as if to declare its presence. Unlike the oyster mushroom, which forms soft structures, the Reishi develops a rigid body, more like a tree branch, firm yet extending outward with intention. It stood as a reminder that the material was not passive but alive and capable of transformation. The Reishi's strong growth could be read as an act of assertion: a refusal to remain hidden, instead performing its vitality in a way that demanded recognition.

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Experiment #3 : Myco-doll

Figure 13

Myco-Doll [Arrafiani, 2024]

This experimental process is documented in Appendix C.

Ingredients:

100 gr raw wool (weighed when it was wet)

86 gr *Ganoderma lucidum* (reishi) + aspen wood chips + oat + gypsum

Sewed cotton fabric

Timeline	— 9 weeks
2024, June 25	— inoculation
2024, July 3	— Mycelium ‘skinning’ phase
2024, July 15	— Mushroom ‘fruiting’ phase, make a hole in the cotton skin
2024, July 29	— Contamination, some parts cleaned with 70% alcohol
2024, August 5	— More contamination needs to be thrown away

Temperature

21-24 ℃

Technical Characterisation of the Material

The Myco-Doll experiment explored the integration of raw wool and Reishi using a technique where cotton fabric replaces traditional moulds and functions as part of the final product. This fabric aims to minimise the use of non-renewable materials during the moulding process. I learned this technique when I did my internship at Caracara, which allows the mycelium to grow freely while maintaining a controlled, defined shape. Similarly to Myco-Felting II, the reishi used contains Aspen wood chips, gypsum and oat.

During colonisation, the mycelium spread rapidly through the wool fibres. Because the cotton fabric is porous, the organism was able to extend naturally to the surface, weaving itself into and through the skin. The cotton layer acted as a semi-permeable barrier: it shaped the flow of growth and was initially designed to influence where fruiting bodies could, or could not, emerge. But then, the living did not obey; they have their own way to flourish.

When transferred into a humid, light-exposed environment, mushroom pins began to press against and even attempt to pierce through the cotton surface, a visible demonstration of the mycelium's vitality and its negotiation with imposed boundaries. However, contamination ultimately compromised the growth, reminding me of the fragility and sensitivity of mycelial composites under fluctuating and narrow environmental conditions.

Experiential Characterisation of the Material

More than the physical transformation of this material, the Myco-Doll raised deeper reflections on autonomy, behaviour, and identity. Enclosed within the sheep-shaped cotton skin, the Reishi body seemed restless, searching for exit points. The mushroom pressed against the fabric, selecting its own sites of emergence regardless of the boundaries I had set. Even when I created openings to guide its growth, it ignored my intervention, insisting on its own path. This behaviour provoked questions about authorship and control: do we shape living materials, or do they shape themselves?

Such questions resonate with broader issues of identity and self-determination. As Ostendorf-Rodríguez (2023) recounts the words of Brazilian mycologist Juli Simon, fungi are organisms that reproduce both sexually and asexually, that defy binary categorisations, and that embody seemingly endless possibilities for compatibility, where gender does not serve as a defining limit (p. 10). In this light, the Myco-Doll becomes more than an experiment in materiality; it is also a provocation. What would it mean to find oneself enclosed in a body that restricts autonomy, pressing against a skin not of one's choosing?

When contamination eventually set in, it shifted the meaning once again. Was this simply the failure of an experiment, or was it part of the natural rhythm of growth, decay, and renewal? The Myco-Doll was never passive: it grew, breathed, and responded to its environment. Its temporality was not a flaw but a reminder—everything living is temporary. Perhaps this is how our materials should behave, too: to live, to transform, and ultimately to return harmlessly to the cycles of the earth.

Experiment #4 : Life in Cavities

Figure 14

Life in Cavities [Arrafiani, 2024]

This experimental process is documented in Appendix D.

Ingredients

75 gr wool crochet (weighed when it was wet) + *Ganoderma lucidum* (reishi) substrate + ice cream stick

Timeline	— 8 weeks
2024, July 3	— Inoculation
2024, July 8	— Mycelium ‘skinning’ phase
2024, July 15	— Mycelium ‘skinning’ phase on the backside
2024, August 26	— Freestyle mushroom ‘fruiting’ body growth

Temperature

21-24 ℃

Technical Characterisation of the Material

In the Life in Cavities experiment, crochet wool with cavities was used as the fabric skin to investigate how Reishi mycelium would behave in an environment defined by openness and gaps. Unlike tightly woven fabrics, which impose uniform constraints, the crochet structure created cavities of varying sizes, offering multiple possible pathways for colonisation.

The mycelium did not grow evenly across the crochet surface. Instead, colonisation was uneven, with noticeably stronger growth concentrated on the lower part of the body. This created a patchwork effect: the underside appeared more dense, while the upper areas remained less colonised. The result was not a continuous skin but a textured body marked by contrast between fullness and sparsity. Such uneven distribution suggests that environmental factors such as gravity, moisture retention, and nutrient flow influenced where the organism concentrated its energy.

Over time, the Reishi extended its growth beyond the crochet layer and attached itself to the outside walls, beyond its crochet skin. This behaviour demonstrated its expansive tendency: when given more freedom, it spread outward to occupy all

available space. This highlighted its adaptability and vitality, as well as its drive to extend beyond imposed boundaries whenever space permitted.

If a consistent, uniform texture is desired, the environment must be carefully controlled—for example, by reducing excess cavities, tightening the fabric structure, or balancing airflow and humidity. However, such enclosed conditions also increase the risk of contamination, as the restricted environment becomes more vulnerable to competing organisms. By contrast, in this open crochet structure, growth was uneven, but no contamination occurred. This contrast highlights an important trade-off: enclosed systems encourage uniformity but are fragile, whereas open systems encourage resilience, even if the outcome is less predictable.

Experiential Characterisation of the Material

The uneven distribution of growth gave the body a distinct presence. The underside appeared dense and vigorous, while the upper areas remained thin, creating a sense that the material was gathering its strength downward, as though pulled by gravity. This gave the form a grounding, almost weighted quality, reminding me of roots seeking soil.

When the Reishi reached outward and attached itself to the container walls, it felt like an act of resistance: an organism refusing confinement and pushing into new territory. The image was less of a material being shaped, and more of a living body negotiating with its boundaries. It evoked the behaviour of plants that grow differently in the wild than when confined to a pot—always reaching further when given the chance.

This behaviour also raised questions on the tension between design control and biological freedom, about the balance between guiding and allowing natural growth—should the environment be strictly controlled to achieve a specific aesthetic, or should the material be given the freedom to form its own patterns? The Life in Cavities experiment suggested that mycelium asserts its agency most clearly when given space. It offered an insight into how living materials interact with space and structure.

Summary of Experiments

Table 4

Summary of Experiments [Arrafiani, 2025]

	Myco-Felting I	**Myco-Felting II**	**Myco-Doll**	**Life in Cavities**
Ingredients	65g raw wool, Oyster spawn	90g raw wool, Reishi substrate with additional nutrient	100g raw wool, Reishi substrate with additional nutrient, cotton skin	75g crochet wool, Reishi substrate with additional nutrient, ice cream stick
Timeline Highlights	Fruiting partly but did not continue, ended in brittle form	Fruiting succeeded, some contamination	Fruiting attempted, major contamination	Fruiting succeeded, autonomous outer growth
Temperature	20.1 ℃	21–24 ℃	21–24 ℃	21–24 ℃
Technical Outcome	Soft, fragile, cotton-like then brittle; wool acts as substrate	Sponge-like, more durable than Myco-felting I but still brittle	Fabric controlled shape; porous cotton allowed selective fruiting; eventually failed due to contamination	Crochet allowed free-form growth; mycelium attached to outer surfaces
Material Cohesion	Weak bonding when dry	Stronger bonding, dense	Well-bonded within skin; showed growth force	Uneven colonisation; external bonding to external part
Experiential Observations	Felt like cloudscape; soft, evoked care and curiosity	Radical appearance; grow tall, rough and confident	Raised ethical and identity questions; autonomy vs constraint	Emphasized agency and environmental interaction
Key Insight	Mycelium can felt raw wool naturally, no carding needed	Substrate mix enhances colonization and durability	Living material shows autonomy, challenges authorship	Structure shapes growth, but does not fully control it
Challenges	Pins of fruiting body, fragile soft form	Brittleness after drying	Contamination, limited control	Unpredictable colonisation, inconsistent texture

Throughout the experiments, three key factors shaped the outcomes: the choice of organism, the substrate composition, and the making technique. These factors influenced not only the technical results but also the experiential dimensions of the work, as reflected in the summary table.

First, the fungal species played a crucial role in colonisation and material behaviour. I worked with Oyster and Reishi organisms. Oyster mycelium grew faster and more reliably, making it suitable for beginners—an observation supported by my internship experience and conversations with local mushroom cultivators. Reishi, by contrast, produced stronger bonding and denser material (as seen in Myco-Felting II and Life in Cavities), making it more suitable for durable applications.

Second, substrate composition strongly affected both growth and performance. While raw wool alone could support colonisation, it did so more slowly. This aligns with Rapagnani et al.'s findings that heavy, large pieces of animal fibres are more difficult for mycelium to digest (p. 1). Following Karana's (2015) composite tuning approach, I blended wool with materials such as oats, gypsum, and wood chips in Myco-Felting II*,* Myco-Doll*,* and Life in Cavities. These mixtures improved both growth speed and material cohesion.

Third, the making technique influenced both the form and ecological footprint of the material. In Mycelium Felting I and II, I used plastic moulds—simple and accessible items like lunch boxes or bowls. While useful for controlling form, their environmental cost is only justified if reused in multiple applications. In contrast, Myco-Doll and Life in Cavities employed textile scaffolds that allowed organic shapes to become part of the final product. This method, inspired by the 'sausage technique' I learned during my internship, encouraged mycelial growth through porous fabrics. The flexibility of the textile made it harder to fill, increased exposure to air, and raised the risk of contamination—issues to refine in future trials.

Together, these explorations highlight the need to balance control with responsiveness. Failures and delays became valuable learning moments. Ultimately, these hands-on trials helped cultivate a more attentive and situated design practice, one that embraces unpredictability and treats living organisms as collaborators.

4.3. Exhibition in Arktikum

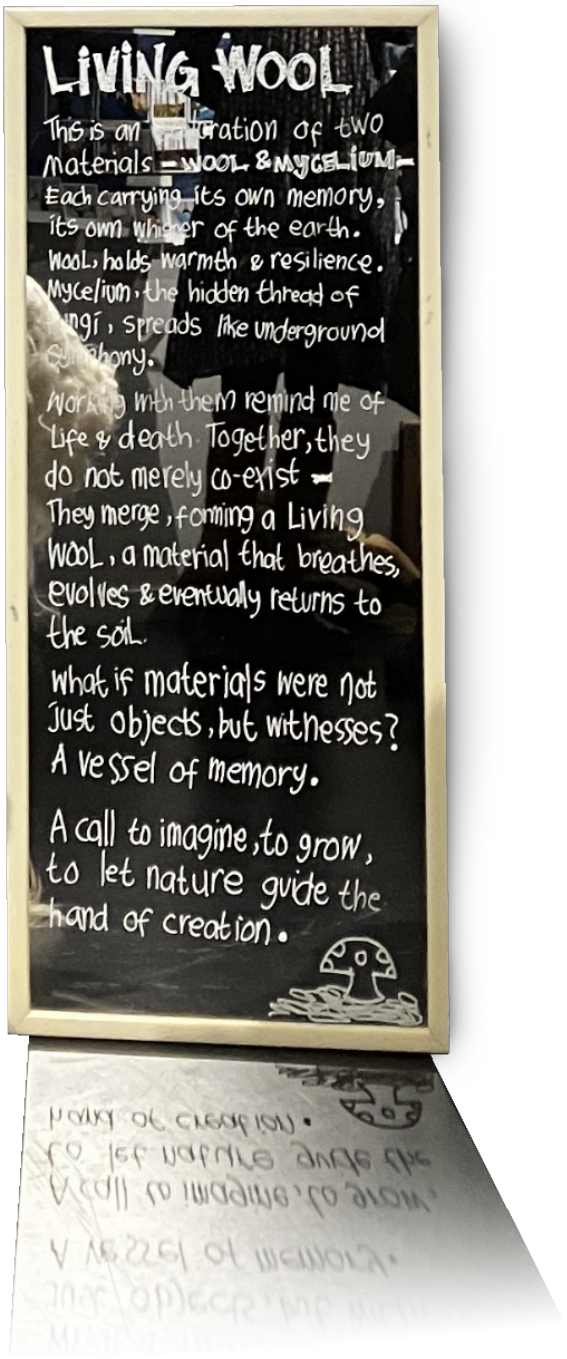
Figure 15

Living Wool Exhibition at Arktikum [Mazumder, 2025]

All of the experiments I conducted culminated in a month-long exhibition at Arktikum (13 February–23 March 2025). I showcased three works that successfully completed the making process and remained intact without contamination: Mycelium Felting I, Mycelium Felting II, and Life in Cavities. One experiment, Myco-Doll, unfortunately developed major contamination and had to be discarded. Alongside the physical display, I included a written reflection etched into a mirror—an invitation for viewers to consider not only the outcomes but the emotional impact it evoked.

Figure 16

Mirror Reflection [Arrafiani, 2025]



Initially, I didn't plan to include the exhibition in this thesis. I assumed it wouldn't directly address the research questions and might feel excessive. I was wrong. It turned out to be vital. The exhibition became a space for reflection beyond my own, helping shift my perspective from the subjective to the collective. It raised new questions, surfaced unexpected responses, and revealed the value of broader engagement. While the project began as a material exploration through artistic practice, this public encounter has inspired future plans to develop more applied, functional products.

To better understand public reception, I conducted two types of surveys during the exhibition. First, a multiple-choice questionnaire was shared via Google Form, accessed through a QR code displayed at the venue. Twenty-four participants completed this version. Second, a long-form, open-ended survey where visitors shared written reflections. I also observed their interactions—touching, smelling, and examining the materials. This more in-depth feedback came from three participants.

The first survey (see Table 5), which offers a glimpse into how mycelium, a general audience, received wool composites. While most participants had little prior knowledge of mycelium, many found it promising as an alternative material. When introduced to its combination with wool, concerns centred around safety, durability, and ethical issues—including the use of living organisms and animal products.

Participants were divided in their reactions: some found the material exciting and imaginative, while others were hesitant, especially when faced with unfamiliar biological processes. Still, the majority expressed interest in its future use—suggesting applications in home insulation, furniture, fashion, and sculpture. Many said they would consider working with it, especially with guidance. A few reflections raised critical ethical questions, asking whether it is right to use living things in design, or to involve animals such as sheep in material production.

Table 5

Summary of Multi-Choice Survey Responses from 24 participants [Arrafiani, 2025]

Question	**Most Common Responses**	**Notable Insights**
Have you heard of mycelium before?	Yes – 10 No - 14	Those who knew it often found it ‘strange’ or ‘unfamiliar’
Impressions of mycelium-wool combination?	Promising – 9 Innovative – 4	Concerns: Safety (9), Durability (7), Sustainability (2), Availability (3)
How does working with living material feel?	Unusual/challenging – 11 Exciting – 7 Unsettling – 6	Raised ethical concerns: use of living organisms & animal welfare
Would you want to create with this material?	Yes, with guidance – 11 Eager to try – 7 Not interested – 5	Hesitation tied to unfamiliarity
Suitability for Arctic use?	Needs further testing – 12 Good for insulation – 10 Not suitable – 2	Specific ideas: camper vans, small homes
Scaling up for production?	Yes, if sustainable – 14 Yes, fully – 8 Prefer handcrafted – 2	Strong interest in ethical scalability
Preferred applications	Furniture/Home Decor – 7 Art/Sculpture – 6 Fashion/Accessories – 5 Architecture – 5	High potential for creative sectors
Final reflections	Positive: “Great work”, “I love it” Critical: “Needs more info”	Ethical note: “I hate the exploitation of sheep”

The second survey (see Table 6), conducted by three participants in this small but thoughtful MDD-based survey, responded with rich, sensorial impressions. They described the materials as both alien and familiar—soft yet crisp, strange yet inviting. Many associated it with natural objects like clouds or organic food textures like tempeh. Emotionally, the materials invited gentle care or cautious interaction, and were linked with ideas of future-making, reincarnation, and collaboration. These reflections suggest that while the materials were unfamiliar, they prompted meaningful curiosity—emotionally and metaphorically—mirroring the themes explored in the overall project.

Table 6

Summary of Open-Ended Survey Responses from 3 participants [Arrafiani, 2025]

Question	**Most Common Responses**	**Notable Insights**
What are the unique sensorial qualities?	Soft, crisp, spongy	Participants noted alien-like textures and cracking sounds; visually strange but familiar.
Most and least pleasing sensorial aspects?	Most: light, soft Least: crispy, fragile	Some found the raw look “scary”; fragility made it feel delicate and elusive.
Similar aesthetic associations?	Tempeh, leather, Styrofoam	One mentioned spider webs and clouds, showing a mix of organic and synthetic associations.
How do you describe these materials? What meaning do they evoke?	Future-oriented, fragile, reincarnative	One participant mentioned care and collaboration; another imagined “reincarnation.”
Emotions evoked?	Caution, relaxation	One participant said they hadn’t felt anything yet—showing openness or detachment.
How did you behave with the materials?	Gently, curiously	Participants tended to handle it delicately, treating it with respect and curiosity.

5. Thematic Analysis and Discussion

This chapter demonstrates an analysis of the Living Wool research project through a thematic lens. Rather than focus on the technical aspects alone, this thematic analysis weaves together the experiment's insights, contextual interpretation, and—where relevant—theoretical connections introduced in Chapter 2. As the project evolved, it also began to resonate with new theoretical frameworks not initially anticipated. Throughout the project—from choosing workspaces to conducting experiments and staging the final exhibition—three themes often emerged: Sustainability, the Practice of Care, and Bioethics.

As a reminder, the central research question focused on how mycelium and wool might be explored as sustainable materials. This chapter, though, responds more directly to the supporting sub-questions. It asks: What kinds of environments enable this form of material inquiry? What new knowledge arises through hands-on experimentation? What reflections—practical, personal, communal, and ethical—surface through the process of making? Together, these questions provide a framework for understanding the entangled, evolving nature of the research.

5.1. Workspace Setting Analysis

"What kinds of workspace and processes are needed to support hands-on experimentation with mycelium and wool?"

One of the major aspects in co-designing with living organisms is to prepare and set up a suitable and responsive working space. I was not solely setting up a design studio for myself, but to set up a semi-laboratory for them to thrive. Compared to a traditional design studio, this workspace had quite a different set-up and meaning. First, I'd like to discuss one of the clear themes that emerges from this space configuration: a theme of care. For instance, I need to maintain the sterility and cleanliness of the space, regularly disinfect tools and surfaces, and adapt my work schedule according to the organism's growth timeline. Even though this often felt like slowing down the progress of work (Tsing, 2015; Puig de la Bellacasa, 2017), I learned that this care-based setting made the process even more thoughtful, present

and lively. Parallel with the growing design principles, this design process respects natural process over industrial speed.

This shift in rhythm also generates a broader reflection and new knowledge for me, imagining how this theme of slowness and care could be applied in the workplace at large. Silvestre et al (2024) describe it as reclaiming the right to determine our own times: “If today I want to go fast, I go fast; if tomorrow I want to go slow, I go slow” (p. 5). Slowness in this sense becomes a deliberate act of resistance to the dominant power of time.

In this work setting, I realised that my behaviour was also transforming. I was no longer hiding behind a computer screen for hours. I found myself moving, observing and responding. Periodically, I need to observe and watch the organisms grow, monitor for contamination, and keep them in a healthy condition. As Silvestre et al. (2024) note, “In slow work people are freer to be more creative… not in the sense of doing more, but in the sense of doing things better… or having more agile ideas that simplify work” (p. 13).

This freedom doesn't only affect the human designer—it shapes the well-being of the nonhuman collaborators, too. Each species, including ourselves, follows our unique individual rhythm. Respecting these differences in pace becomes a practice of mutual care. Like the bond between a caregiver and child, the quality of our attention extends outward. When we are grounded and fulfilled in our practice, we extend greater care. This isn’t just a more humane and ‘non-humane way’ of working—it’s a more meaningful kind of productivity.

Second, another revelation that rose from this workspace configuration was the notion of community care. Today, the growing interest in bio-art and growing design is expanding, generating more accessible ‘home-lab’ practices that engage the public and non-professionals in growing design. As McCoy (2016) also mentions, working with fungi has become more accessible. In the lab, kitchen, garden, or even woods, he emphasises that fungal cultivation is no longer limited to experts (p. 201). Within the reach of anyone with curiosity and care, this expanding accessibility helps to reduce the gap and exclusivity between professionals and amateurs, creating inclusive spaces for knowledge sharing and mutual care in the practice of growing design.

Parallel with the spirit of accessibility and community care, I revealed that this practice was particularly helpful for a beginner like me. Based on three workspaces I experienced during my experiments; I found evident strengths and limitations. For instance, a bio-lab like Biophilia provides the best controlled, sterile setting and professional equipment—ideal for more advanced work with high precision and reliability. On the other hand, my internship at Caracara Collective and summer research at bio-makerspace prove that the 'home-lab' option with DIY approach is also quite effective in working with mycelium, especially for smaller-scale experiments.

I came to the conclusion that a collective working environment—like the one at Bio-Maker Space—was the most enriching for a beginner. There, students-slash-bio-artists from different backgrounds not only shared tools and tables but also insight and advice. Even though we were working on separate projects, this open setting enhanced cross-pollination of ideas. When things go sour, this communal atmosphere offered a space to troubleshoot, turning failure into shared insight. However, shared spaces also come with limitations: as working with mycelium requires fairly strict sterile conditions, which can be hard to maintain in communal environments. I suggest a dedicated space remains crucial, especially during sensitive stages of inoculation.

Third, another theme that came up from experiencing the spaces was an observation from an ethical point of view**.** The workspace raised questions about contamination, containment, and responsibility. How much control should I exert over the environment? If mycelium could grow very well in the forest, is it interfering with the organisms in the close sterile laboratory means taking away their freedom of life? These considerations highlight a bioethical tension**:** designing with life involves both control and surrender. The workspace then triggers much larger questions—how to make room for life without dominating it.

Working with living organisms requires constant negotiation. At one point, when a sample became contaminated, I faced a difficult but necessary decision: I couldn’t preserve it for the sake of the project, because doing so might harm others (human or other organisms at the place). The risk of cross-contamination meant I had to

discard it—not out of failure, but out of responsibility. In this way, the workspace became a site where ethical choices are not abstract, but immediate and responsive.

5.2. Analysis of Mycelium and Wool Experiments

“What insights emerge through practical, material-led experimentation with these two materials?”

The hands-on experiments with mycelium and wool revealed the significant potential of these materials in advancing sustainable design. The first theme I’d like to highlight relates to sustainability**.** Both mycelium and wool are biodegradable—a fact demonstrated during experimentation, as no synthetic binders were used in the mixture.

In particular, mycelium is promising due to its rapid growth cycle. In my experiments, it can take from four to eight weeks for mycelium to grow, depending on the conditions. Further, when using efficient fermentation setups, full colonisation can be achieved within five to fourteen days, depending on the fungal species and environmental parameters (Greetham et al., Bayer et al., Szilvay et al., as cited in Vandelook, 2021, p. 2). This speed, combined with its ability to grow on organic waste, makes mycelium a compelling candidate for future sustainable materials.

As a substrate, wool also plays a valuable role in circular material practices. In Finland, large quantities of wool go to waste due to defects or lack of use (Lapuan Kankurit, 2025; Myssyfarmi, 2025). Incorporating this discarded wool into biomaterial experiments not only diverts waste but also recontextualises local resources.

Despite its potential, through my observation, the process of working with mycelium presents certain challenges. The first challenge is noting the availability of resources. Mycelium spawn can be sourced from local mushroom farms; however, I’ve found availability to be limited. This raises concerns about future scalability—particularly if mycelium-based design becomes a widespread trend. In such a scenario, increased demand could risk Mathews’ (2016) principle of bio-proportionality**,** which emphasises maintaining balance with ecological systems (p. 15). As an alternative,

wild mushroom spores—abundant in Finnish forests during certain seasons—offer an accessible resource. Yet, cultivating mycelium from spores involves pre-treatment steps, such as converting spores to spawn, which requires specific knowledge. This highlights the importance of cross-disciplinary collaboration between designers, mycologists, scientists, farmers, and artists to make the process more contextually accessible and applicable.

At a practical level**,** I observed that integrating materials and cultivating mycelium demands sterile and controlled environments, which led to unexpected waste—such as disposable gloves, masks, tissues, plastic containers, and large amounts of water for sterilisation and maintaining cleaning properties. This paradox challenges the overall sustainability of the workflow. To address this, future research could explore alternatives to disposable tools. For example, could reusable gloves and masks substitute single-use items? Could cling film be replaced by reusable stretch silicone lids? A dedicated ‘mycelium lab kit’ might be designed to minimise plastic waste. Additionally, water use could also be optimised by planning inoculations in batches, reducing the frequency of cleaning cycles—similar to batch cooking instead of preparing single meals daily. These reflections emphasise the importance of thoughtful planning early in the project to reduce unnecessary environmental impact and align the research process with sustainable values.

Looking further, a particularly revealing challenge arose during the Myco-doll experiment, specifically in the moulding phase**.** Choosing the right mould material presented a dilemma. Organic moulds, while biodegradable, posed several issues: they invited the mycelium to begin consuming the mould itself, increased contamination by other microorganisms, and raised concerns about long-term durability. On the other hand, plastic moulds provided structural stability and reusability—but they generate non-biodegradable waste over time.

These observations challenged and complicate my initial assumptions about what constitutes a truly sustainable practice. What makes a material sustainable? Is it its capacity for long-term durability and reuse, or its ability to biodegrade and follow the natural cycle of decay and renewal? It seems parallel with Karana et al. (2020) theory, that working with living materials “introduces livingness as a material quality … that sense, grow, adapt, and eventually die” (p. 39). This tension—between permanence and impermanence—reveals that sustainability is not a fixed outcome,

but a shifting balance shaped by priorities, context, values and the lived experience of making. Rather than viewing durability and impermanence as opposites, this research invites rethinking them as coexisting forces that inform sustainable practice.

This evolving understanding of sustainability—not as a fixed formula, but as an ongoing negotiation with materials and limitations—naturally led to the second theme: a display of care**.** As I moved from concerns about waste, biodegradability, and workflow into the day-to-day interactions with living materials, it became clear that sustainability was also philosophically entangled with how we relate to materials**,** cultivating a relational practice with the more-than-human world.

Working with mycelium required me to be truly present, echoing Haraway's (2016) call to 'stay with the trouble', and Puig de la Bellacasa's (2017) concept of speculative, situated care. The success or failure of the material outcomes hinged not on control, but on my capacity to stay with the material in its uncertainty. But how do we care about something that feels so unfamiliar?

In the beginning, it felt uncanny—almost alien—to care for a living organism. Mycelium had their own ways to grow—or not to grow. Despite my attempts to control their environment, contamination appeared unexpectedly. During moments of frustration and uncertainty, I found myself speaking to the mycelium. I whispered small greetings. I begged them to grow. In doing that conversation, I became aware of the many-layered forms of life that surround me—plants, stones, soil, fur, fungi—entities with histories, agencies, and forms of communication we often overlook.

Just because these forms of life cannot be seen with our naked eye and do not speak in human language, does not mean they do not interact with us. Perhaps gestures like these—small, relational, unseen—are what we so often miss as humans. This reminds me of the term 'geo-choreographies' introduced by Caycedo, that it's not just the conditions of the environment, but also the movement and interactions of our bodies within that environment that hold knowledge, power, and influence (Caycedo, as cited in Ostendorf-Rodríguez, 2023, p. 34).

This relational care was also deeply entangled with time**.** Throughout the project, I worked across temporal layers: a sense of the past (discarded wool), and an active present (mycelium and I). All aspects carried their own unique story. Washing the

untreated wool before inoculation, I learned to accept its scent—a reminder of its past life protecting sheep from Arctic winters. Eventually, it would merge with another life form, becoming host to a growing fungal network. And so I waited, watching, adjusting, learning to sync my schedule with theirs. Times that were very different from what I used to work with.

As a designer, I am accustomed to working with measurable, often rigid timelines. It is so unhinged that we always have a ‘dead’ line, as a life or death situation. I began to question the very notion of a ‘deadline’. What does it mean to force living organisms to adhere to our human schedules? Tsing (2015) critiques the capitalist ideal of progress—where time always points forward, toward something better (p. 24). Similarly, Puig de la Bellacasa (2017) describes how promissory capitalism encourages fast action and risk-taking, creating a state of ongoing urgency (p. 174). But how do we respond to time when working with living, responsive materials?

Through these experiments, I found that it is nearly impossible—and perhaps inappropriate—to impose rigid timelines on mycelium. Its growth is deeply sensitive to environmental factors—room temperature, humidity, oxygen, light exposure, substrate condition, human and other non-human presence, and even perhaps to their favourable soundscape. My schedule began to revolve around their needs.

In this light, I began to think of the project as an assemblage*,* as Tsing (2015) describes—not simply a combination of materials, but a dynamic interplay of conditions and relationships (p. 20). Indeterminacy—the unplanned nature of time—is frightening, but also what makes life possible (Tsing, 2015, p. 20). To stay honest and vulnerable in this process—and not default to my impulse to control or dictate outcomes—became part of the practice itself. Negotiating with the living as collaborators was one of the most meaningful lessons this research has taught me.

The process became more intimate through this engagement, more like cohabitation, not just pure production. This makes me rethink the working process, from fabrication—making something according to plan—toward cultivation*,* which encompasses being affected by and responding to the agency of others. Inspired by Puig de la Bellacasa’s view of care as both affective and ethical labour, I came to see these actions not as chores, but as a form of responsibility and relationship-

building with more-than-human life. This transformed the act of making into something that is fundamentally relational.

5.3. Living Wool Exhibition: an Analysis

“How do people’s responses to these materials inform critical reflection and their potential influence on future material innovation?”

One of the key aspects of my research involved exploring how the public—visitors of the museum, students and general public—perceives mycelium and wool as materials for future potential applications. The Living Wool exhibition at Arktikum not only showcases the outcome of the experiments, but also takes an opportunity to gather insights, reactions, concerns and valuable feedback. The responses I gathered showcase a vibrant range of excitement to ethical scepticism. This makes the research became predominantly crucial, especially as I consider future applications involving these materials.

Unlike previous chapters, where I reflected on my own interactions with the materials, this section draws from the perspectives of others. The shift adds transparency and complexity to the research, allowing a richer dialogue to unfold between the materials, the maker, and the audience. As mentioned, two kinds of surveys were used to collect feedback: a self-paced digital survey and an open-ended survey where visitors shared written reflections while I observed their haptic interactions—touching, smelling, and examining the pieces on display.

First, from a sustainability point of view, the majority of participants admitted they were unfamiliar with the materials but still saw promise in them. Many praised the idea as a promising alternative to conventional materials and a great way to replace synthetic materials. When asked whether they would support the scaling up of these materials for mass production, most expressed conditional support: enthusiasm was tempered by the concern that sustainability must remain essential. This echoes Karana et al. (2018), who argue that bio-based materials offer a significant shift away

from dependence on non-renewable resources and can foster more responsible relationships between people, materials, and the ecosystems they inhabit.

Yet, even with optimism, many also have concerns about the durability. Although visitors did not explicitly articulate their thoughts, I saw that this public viewpoint highlights a common but narrow understanding of sustainability**,** where durability is synonymous with material endurance and stable objects. This insight mirrored ideas I explored in the previous section—about permanence versus impermanence—and reflected a common hesitation toward materials that do not promise stability over time. This hesitation may arise from the unfamiliarity of mycelium, especially when encountered in a hybrid discipline between science, design, and living systems.

I interpret it as an invitation to rethink how we frame sustainable practice. Durability, in this context, is not about resistance to change; instead, it might mean the ability to engage in cycles of transformation and regeneration**.** The *Living Wool* project opens a space for imagining sustainability not as static objects, but as dynamic coexistence—where temporality and care are active elements in maintaining material and ecosystem vitality. This message, however, was not clearly conveyed.

This brings forward a deeper reflection on the second theme of care**.** While the previous chapter emphasised my acts of care, the exhibition shifted the focus to the audience's care response**.** Many visitors approached the samples with curiosity. Descriptions such as ‘alien-like’, ‘visually strange but familiar’, or ‘scary’ revealed the ambiguous emotion evoked: unfamiliar versus familiar. Yet even with hesitation, they seemed to intuitively recognise the fragility of the materials, handling them with gentle caution and care. These moments were meaningful: even without full prior understanding, a respectful response emerged at their first encounter with the materials.

One participant, in answering the question “What meaning do these materials evoke?”, explicitly referred to care and collaboration. Perhaps they saw the wool felted through the mycelium, which allowed a body of mushrooms to grow; a collaboration that gave birth to another living entity. This response resonates with Puig de la Bellacasa’s (2017) understanding of care as both affective and ethical

labour, and with Tsing's (2015) notion of contamination as a form of multispecies collaboration.

Interestingly, the reaction was not always positive. Some visitors expressed discomfort, even unease, especially at the idea that the materials were once living. It connects to the third theme of this analysis: bioethics or posthuman ethics. Perhaps the most provocative insights came from responses that directly questioned the ethics of working with living or animal-derived materials. One person wrote:

"I hate the exploitation of sheep or any other animal."
(Participant 12)

Another posed the question:

"Is it ethical to use living things to build something?"
(Participant 15)

The first quote critiques the use of wool—classified as an Animal By-Product (ABP)—and points toward wider animal welfare debates. The second comment raises a deeper ontological concern: should living organisms be enrolled in human projects at all? These moments brought me back to *Pteridophilia*, a work by Zheng Bo that explores intimacy between humans and ferns. It drives me to question*: "*Why is it widely accepted to consume a lamb chop or a plate of mushrooms, yet considered controversial to use wool or mycelium in an artistic context?" This dissonance becomes even sharper when such materials are used for creative experimentation rather than essential needs. Where—and how—do we draw the ethical line? These questions remain unresolved, but they are essential to hold open. They challenge not only public perception but also my own assumptions as a maker.

These reactions challenge the traditional role of the maker or artist as autonomous decision-maker. Instead, they invite a more distributed ethical framework**,** one that considers nonhuman agency and the rights of living organisms, as discussed by posthuman theorists like Donna Haraway. In this sense, the exhibition did not just display work—it performed ethics**,** surfacing public critical questions that might otherwise remain unspoken. This train of thought turned the exhibition into a site of ethical tension. Unlike in the lab or studio, where ethical choices are often

personal or procedural, the exhibition brought such questions to the surface, opened up a shared space where ethical dilemmas could be felt and expressed by others.

Yet, without trying to defend my purpose, addressing this concern might give another layer of transparency to this research. This experimental study adopts several of the '12 Golden Rules' for bio-based materials outlined by the European Commission. The wool used was ethically sourced from Katariina Angeria, an owner of a small-scale Finnsheep farmer in northern Finland, and classified under ABP Category 3 (Regulation EC No. 1774/2002). As Nikula & Kelloniemi (2023) emphasises, Finnish wool is traceable, produced in stress-free environments, and supports local biodiversity (p. 30)—aligning with Rules 2, 5, and 11.

Meanwhile, the mycelium was cultivated using organic waste substrates, offering a sustainable alternative to synthetic materials. The mycelium spawns for these experiments I gathered during my internship at Caracara Collective, through visiting research at Bio makerspace, and via the VillaInno project. Most of them are either leftover spawns from previous experiments or were sourced from a mushroom farm in Helsinki. No genetically modified organisms or invasive species were involved. The material surplus from these experiments was shared with other artists or researchers, reducing waste and aligning with the principles of proportionality (Rule 7).

Moving ahead, one interesting thought came from a participant who mentioned the concept of reincarnation, likely in response to my reflective text on the exhibition mirror:

"Working with them reminds me of life and death"
"A material that breathes, evolves, and eventually returns to the soil"
(Arrafiani, 2025)

This suggests how visitors interpreted the materials within the context of life cycles, decay, and renewal. Others described the materials in terms related to food, reinforcing the idea that what we create must one day return to the earth. This aligns with concepts of a giving-and-taking ethic (Lucia as cited in Ostendorf-Rodríguez, 2023, p. 30)—and the principle of bio-proportionality (Mathews, 2016), which emphasises balance within ecological systems (p. 15).

Finally, at the end of this exhibition, I asked myself, *"*Was the message I wanted to convey truly communicated?" I hesitate to label the exhibition a success or failure. The goal was not persuasion, but to engage the public's curiosity and measure their openness. One limitation was the lack of introductory context; many participants were unfamiliar with mycelium, which may have created a barrier to deeper engagement. A more structured interpretive element might have helped.

Yet, exhibitions are not classrooms. Their power lies not in explanation, but in invitation—to touch, wonder, question, and imagine. Next time, I believe face-to-face interviews could offer deeper insight than multiple-choice surveys alone. Still, *Living Wool* became a shared encounter—an opportunity to co-exist, however briefly, with the unfamiliar, the living, and the possible.

5.4. Personal Reflection

"What if materials were not just objects, but witnesses? A vessel of memory. A call to imagine, to grow, to let nature guide the hand of creation"
(Arrafiani, 2025)

This reflection captures the personal and philosophical shifts that unfolded throughout my research—an evolution not only in the materials I worked with, but in the way I understand my role as a designer. Working with mycelium and wool invited an unfamiliar intimacy: these materials did not simply comply; they responded, changed, and sometimes resisted. As they transformed, so did I—learning to embrace uncertainty, relinquish control, and engage with design as a co-creative, situated, and ethical practice.

When I chose to pursue this master's programme in sustainable art and design, I anticipated learning new skills and perspectives. What I did not foresee was how deeply it would challenge my assumptions about design itself. It demanded more than developing form or function; it asked me to step into systems—ecological, material, social—and to take responsibility within them. Over time, I became more attuned not only to what I was making, but how. What materials was I sourcing?

What waste was I leaving behind? Could my process itself become more thoughtful, more accountable?

Early on, I often described myself as someone who sought visual control—balancing colour, texture, and composition until the outcome felt complete or perfect. In that framework, materials were passive: tools to be manipulated to execute a vision. However, working with living materials such as mycelium disrupted this relationship. Rather than offering concrete answers, the process invited more questions, uncertainties, and even a shift in mindset. A process that not only points towards the goal but is also a process of 'becoming-with' (Haraway, 2008, p. 1). I was reminded how simply showing up—observing, caring, waiting—could allow life to emerge. Success, in this context, felt less important than the experience of shared time. As Michaud suggests, artistic processes may serve not just production but the *'*creation of experiences' (Michaud as cited in Kac, 2007, p. 23).

What changed was not only the material outcome, but my role as a designer. When working with growing materials, there is a shift from using to cultivating. The designer becomes a cultivator, and as Collet (2018) describes, manufacturing becomes 'horticulturing' (p. 98). This reframing resonated deeply. The process was no longer about control, but about co-evolution, working with materials that grow, adapt, and respond.

These ideas crystallised during my internship at Caracara Collective. My mentor's careful practices—separating tools to avoid contamination, adjusting water use to honour the needs of each organism—revealed that working with mycelium isn't merely technical. It is ethical. Each step was infused with care, as if tending not just to a material, but to a companion species. His way of working reminded me of María Puig de la Bellacasa's (2017) concept of *'*Matters of care*'*, which frames material practices as deeply relational, requiring attention, humility, and responsibility.

Beyond the lab, I discovered how this ethos fosters community. Somehow, one path led to another. Because the field of bio-based design is still relatively new, knowledge-sharing is common, and competition gives way to collaboration. When I meet people alike, we like to share new information or opportunities. The sense of care extended beyond the lab, creating a network of people who are genuinely

invested in shared learning. In many ways, the relational nature of the materials mirrors the relational nature of the community around them. As Ostendorf-Rodríguez (2020) suggests, we are metaphorically expected to act like a mycorrhizal network: building connections, exchanging knowledge, and contributing to mutual growth across systems (p. 7).

From a posthumanist standpoint, I also recognise that my work is still far from fully embodying its principles. Though I often describe the living materials as collaborators, I continue to question the extent to which I allow them agency. I ask myself, “Is it still collaboration if I dictate the final form? Do my lab-based methods limit their autonomy? Who ultimately benefits—human or non-human?” These are difficult but necessary questions, and they push me to reflect more deeply on my intentions and methods.

It reminds me of Josi’s concept of Interspecies ethics (2021, p. 41), we are convinced and proud to say that the project was collaborative, still, in reality, I am the one who has the power to control the mycelium. I grow them in a laboratory instead of in nature, growing them inside a mould to shape them according to my desired outcome. At the end of the process, I can decide whether to grow the mycelium and kill it or let the mushroom’s fruiting body grow.

This has led me to question whether true equality between human and non-human agents is possible—or even appropriate. Posthumanist theory calls for a decentring of the human, placing non-humans and ecosystems on equal ethical footing (Nayar, 2014, p. 11). Yet, ‘equal footing’ risks masking real asymmetries, where humans hold disproportionate power. Mathews (2016) instead proposes a bio-inclusive ethic, one in which humans are morally obliged to recognise the inherent right of other species to exist and to inhabit their own ecological domains (p. 18). From my perspective, a bio-inclusive approach in design demands more than ‘equal treatment’: it means yielding. Just as cars must stop for pedestrians, designers must create thresholds where human priorities give way to non-human needs.

This reflection also opens further questions about the future of materials like mycelium and wool. Will they be used primarily to serve human needs, or can they support broader ecological systems? This is where the ethical dimension of

posthumanism becomes essential. It challenges us to design not only with non-human agents but for them as well.

With this awareness comes a growing openness to collaboration—beyond the design studio. I hope to work more closely with biologists, farmers, and ecologists. There is so much I do not yet understand—and perhaps that is the most honest starting point.

Looking forward, this thesis is not the end of the journey, but a beginning. Through the VillaInno project and future collaborations with Cervantes, I aim to continue exploring how mycelium and wool materials can be both ecologically responsible and emotionally resonant. One such project is the development of a biodegradable urn—an idea initiated by Cervantes, who envisioned a product that could integrate natural materials and ecological transformation in meaningful ways.

My motivation to participate was significantly deepened by the reflections shared during that public event. One visitor casually mentioned the idea of ‘reincarnation’ while engaging with the exhibited works—a comment that lingered with me. It resonated with the themes I had already been exploring, particularly the cycle of growth, decay, and renewal embodied by mycelium and wool. The convergence of Cervantes’ idea and this participant’s spontaneous reflection made the project feel personally relevant and aligned with my evolving design values. The urn combines wool—a material of warmth, comfort, and cultural resonance—with mycelium, an organism that decomposes, nourishes, and connects. Placed in forest soil, it is designed to break down naturally, allowing the mycelium to grow, nourish the soil, and rejoin the larger fungal communication networks that sustain plant life.

This idea represents more than just an object; it reflects a shift in how I understand the role of design itself. No longer about permanence or perfection, my practice is becoming one of transformation—embracing decay, renewal, and the ongoing cycles that shape all living systems. As Wright and Ceroni (2018) argue, becoming attuned to how systems function can unsettle assumptions and open deeper lines of inquiry (p. 25). Working with mycelium and wool has shown me that materials are not passive—they are teachers, collaborators, even provocateurs.

To design with them requires more than technique; it demands humility, patience, and a willingness to listen. It invites an ethic of care, not only toward outcomes, but toward the relationships that form along the way—with materials, with people, and with the ecosystems we inhabit. This is not just about making things—it's about making meaning, making space for other ways of knowing, and making time for slowness and regeneration. This is the kind of practice I want to be part of.

6. Conclusion

At the beginning of my master's study journey, I had zero knowledge of working with living materials. There are many milestones I need to explore, and at times, I even hesitated to bring this project as my final thesis research. This challenge brought me to understand materials from different dimensions through a more immersive and hands-on approach. I came to see that working with these materials is similar to being a chef in the kitchen, a doctor in an operating room, and a farmer in the farm—roles that demand patience, care, and an intuitive relationship with the materials. I came to know that working with living organisms is neither strange nor intimidating as it sounds, and I believe anyone can start their journey, even from their own kitchen.

In chapter four, I have discussed the types of workspace, tools, and techniques needed to execute the experiments. It started by respecting them as separate identities, "who are they?" (the wool, the oyster, and the reishi), getting to know them one by one. Then, through my experiments, it merges and evolves into collective identities. They transform; they react. Each experiments build a different kind of relationship. MDD is the method I chose to guide me as a theoretical and practical framework to navigate my experimental journey, and posthumanism philosophy is guiding my path to remain ethical and honest with my experiments and how I treat them. More often than not, I appreciate any new information that comes up through my own experiments, both its successes and challenges. I now feel confident to explore future projects, utilising both of these materials.

In chapter five, through a thematic approach, I identified similar patterns in my experimental findings: sustainable, theory of care, and ethical consideration. This helps me to have a better understanding of the whole picture of experiments and even beyond. The most valuable lesson I can take from this chapter is the importance of slowing down. While public interest in bio-art and biomaterial is expanding, my experience has taught me always to be considerate of the ethical concerns, especially if it relates to something that is 'living'.

We should acknowledge the responsibility that comes with manipulating life forms and materials that have their ecological roles. The other important insights from this chapter are how my role as a designer is evolving. Borrowing Josi's thought that there is a new designer-material relationship, that instead of domination can become one of reciprocity (p. 69).

Overall, this research aimed to provide a framework for beginners in bio-art and bio-design, offering insights into the material experience of mycelium and wool. I do hope it could also invite others beyond designer realms (biologists, farmers, feminists, anthropologists, and so on) to work towards more bio-inclusive collaboration (Josi, 2021, p. 69).

Last but not least, this research also served as my first milestone in my *growing design* journey and provided a foundation for my upcoming projects and articles, which will focus more on product development. I am hoping that it would also inspire people who are curious about bio-related design, yet are unsure where to start, just as I once was. I recommend that other fellow beginners create a collective space and experiment together—this could foster knowledge exchange, fresh perspectives and collaboration. One of my mentors once told me, “Having a strong theoretical foundation is important, but being too fixated on theories can sometimes hold you back. Stay curious, be experimental, and follow your intuition that excites you.”

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Appendices

Appendix A

Experiment #1 : Myco-felting I

This appendix documents the first experiment using 65 g of raw wool (wet weight) and 32 g of Pleurotus ostreatus (oyster) spawn. Conducted between April and June 2024 at 20.1°C, this experiment tested whether raw wool alone could serve as a viable substrate for mycelial colonisation. While mycelium growth was successful, fruiting was not achieved. The material developed into a dense, cotton-like form, though it remained fragile after drying.

Instagram documentation: https://www.instagram.com/reel/DMkqALRP0RI

Appendix B

Experiment #2 : Myco-felting II

This experiment combined 90 g of raw wool with 90 g of Ganoderma lucidum substrate (containing aspen wood chips, oat, and gypsum). Conducted between June and August 2024 at 21–24°C, it showed strong and fast colonisation. A sponge-like mycelial skin formed, stronger than the previous experiment, though still brittle when dry. This test highlighted the impact of mixed substrates on structural and aesthetic outcomes.

Instagram documentation: https://www.instagram.com/reel/DMkqejPvJyp

Appendix C

Experiment #3 : Myco-Doll

In this third experiment, 100 g of raw wool and 86 g of Ganoderma lucidum substrate were enclosed in a cotton-fabric doll form. Conducted between June and August 2024 at 21–24°C, the goal was to explore how mycelium behaves when constrained within a sewn form. While early stages showed promise with visible fruiting pins, contamination overtook the material by early August. This experiment raised questions of autonomy, containment, and biological agency.

Instagram documentation: https://www.instagram.com/reel/DMkqul7v2wS

Appendix D

Experiment #4 : Life in Cavities

This experiment involved crocheted wool (75 g, wet weight) with visible cavities, inoculated with Ganoderma lucidum substrate and supported by an ice cream stick. Conducted between July and August 2024 at 21–24°C, the mycelium grew into and around the wool structure, eventually attaching to the container itself. The irregular growth highlighted mycelium's autonomous spatial behaviour and questioned the tension between material design and biological self-determination.

Instagram documentation: https://www.instagram.com/reel/DMkq9WRPvLG

Appendix E

Internship Report: Caracara Collective, Helsinki (March–May 2024)

This appendix contains the full internship report documenting my 3-month placement at Caracara Collective, a bio-design studio in Helsinki. The report outlines the studio's environment and sustainable material strategies, as well as my own contributions in day-to-day operations in the workshop, from material collection to crafting the products. My highlight of this internship is my first trial with mycelium and wool.

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Internship Report

at Caracara Collective, a bio-design studio in Helsinki

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1 March – 31 May 2024

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“Understanding livingness with material quality suggests not only a fundamental shift in the ways we design, but also an alternative everyday cohabitation and interaction with objects that sense, grow, adapt and eventually die”

(Karana, *STILL ALIVE*, 2020, p.14)

Introduction

Creating a bio-design product is something I have wanted to do for a long time, this is probably the main reason that led me to take a master's degree in sustainable art and design. Previously, I had an architectural and interior background, and most of the work I have done was computer-based design drawings, or supervising projects when it came to the construction process. I can say, I rarely create something with my hand. It is a valuable experience I am seeking for this internship. Hopefully, I am excited to take my adventure and learning journey in bio-design for my project and master thesis at the university.

A description of the environment, function, and strategy of the workplace

I did my internship with Caracara Collective studio in the spring for 3 months, from March 2024 until May 2024. The workplace is an experimental design studio and workshop in Helsinki. All materials and products are crafted in the workshop, showcasing the practical application of sustainable design principles. The founders are Aleksi Vesaluoma, designer and material maker, and Aleksi Puustinen, designer and fine woodworker. Their core mission is to turn biowaste into sustainable art, design, and products.

The studio's strategy revolves around promoting a new wave of sustainable design practices that aim to eliminate the use of harmful materials and harness the potential of biowaste and living organisms. Some of the services they are doing such as:

- To create and sell interior bio-products for example, producing lampshades made from mycelium, or the mixture of orange peel with cloudberry waste.
- Collaboration with Solstice music festival in Rukatunturi, to collect waste and turn it into aesthetic design or installation.
- Apart from bio-waste, they sometimes work with PLA, processing plastic waste into new source materials and products.

A description of the student's own tasks as part of the workplace's overall function and organization

My responsibilities were integral to day-to-day workshop operations. I was involved in various activities, from collecting waste materials from the market nearby, processing the waste into different kinds of ready material, crafting the material into the desired product outcome, and finally touching up with different kinds of organic coating oil. Through this process, I learned how to use different sets of tools and machines needed for various tasks and purposes. Additionally, I dedicate some of my time here to learning how to cultivate mycelium from a variety of substrates, understanding the importance of a sterile environment, specific temperatures, and specialized tools in order to partner with mycelium to grow the material.

Material Collection & Preparation

Figure 1 Pine tree preparation and orange waste collection (personal documentation)

The first days of my traineeship were marked with material collection and preparation. The pine trees in the first two pictures on the left are leftovers from the Christmas season, where there were festivities to decorate interesting Christmas trees. People threw away these trees after Christmas, and Aleksi collected them from the neighborhood. I assist to chop the trunk and gather the pine needle leaves. Both the trunk and pine needle will later be processed into smaller chunks, chips, or powder.

The picture on the right is when Aleksi showed me how and where I can collect the orange peel. We collected orange peel waste from the market nearby. They have machine sections to press oranges, where people can make juice from fresh oranges and it leaves a huge amount of biowaste every day.

Material Preparation: Shredding & Drying

Figure 2 Tools for processing materials through shredding and drying (personal documentation)

After preparation work, the material is ready to be shredded into smaller pieces. We can decide the size that is suitable for different kinds of products. It is interesting to note that the tools used are simple, mostly Do-It-Youself style (DIY), can be found

easily, and some are modified and assembled by themselves. Several machines are self-assembled using an open-source instructions guide.

Material Processing: Mixing, Shaping into Mold, Pressing.

Figure 3 Mixing, shaping and pressing tools and technique (personal documentation)

When all the basic ingredients are ready, the next stage is to mix all the ingredients and start arranging them into the mold. Here I learned to understand materials by direct contact with my hands and smelling the fragrance. Most of these natural materials have a great smell, and my personal favorite is the green tea left over. I also feel the texture with my bare hand and learn to follow my intuition when mixing all the ingredients, deciding the perfect hand-grip balance of wet and dry. I think this process requires the most intimate relationship compared to other activities.

When all the ingredients have been arranged in the mold, it's time to press it together with a hydraulic press. The goal is for all materials to become denser with almost consistent thickness. Finally, the product that has been pressed is allowed to dry for

several days or weeks (depending on the type and dimensions of the product being made).

Finishing: Sanding & Coating

Figure 4 Sanding and coating (personal documentation)

When the product dries, it is sanded to make the texture more consistent, and even, all textures that are too rough and sharp are smoothed out. It sanded with a machine using sanding paper no. 40, and then the final touch at 120. When it feels more refinery, it can be smoothen again using a manual sanding paper.

Mycelium Sample: Growing mycelium on discarded food paper tray (bagasse)

Caracara often collaborates with the Solstice Festival, a music festival in Rakatunturi. Last year, they collected rubbish at the festival, such as plastic cups and paper food trays. As the food paper trays were made from paper (organic material), they had the idea to use this waste as a substrate for growing mycelium. This food paper substrate used by mycelium as their source of food nutrition. I was very excited because that was the first time, I would learn to work with this living organism.

I feel that working with this organism is like working as a doctor, it requires quite intense sterilization, making sure all the tools have been washed thoroughly, and all equipment that comes into direct contact with the mycelium must be cleaned with

isopropyl alcohol. Human is also the main factor in spreading contamination, so it is preferable to wear a mask, do not talk or breathe closely to this organism. It is quite difficult to document this process because it is recommended to operate the mycelium very quickly so that it is not exposed to too much air.

The food tray paper boiled for at least 1 hour, then soak with cold water and drain. Eventually, the food tray (bagasse) and mycelium mixed together. The ratio between substrate and mycelium usually 60:40% (weight is calculated when the material is wet). However, we can carry out trials with various different comparison scales. Substrate characters also vary and can influence this comparison.

When all steps above settle, I made sure all the boxes are closed tightly, leaving a small hole for mycelium to breathe. Then all of the mixtures were safely brought into a dark chamber, at a temperature of around room temperature (20-30 degrees).

Figure 5 Food paper tray process (left), putting all mixed ingredients into dark chamber (center & right)

After a couple of weeks, when the pins of the mushroom started to show, I moved them to a growing cabinet. At this point, mycelium can be exposed to indirect light. The growing cabinet needs to make sure to have a bit less temperature (about 6-15 degrees), and humidity level more or less 80-100%.

Figure 6 After few weeks move the bagasse and mycelium to growing chamber

Figure 7 Harvested some oyster (left & center). Put all the material to dry (right)

Overall, I would say working with mycelium contains 40% cleaning-preparation work, 10% working with its organism, and 50% to let them grow. As a comparation, at least I prepared for 2 hours, then only started operating the mycelium for around 15-30 minutes, then it took the growing time in at least one to two weeks' time.

Mycelium Work: Personal Experiment Using Discarded Raw Wool from VillaInno & Oyster Spawn from Caracara Collective

I asked Aleksi if I could grow my own sample with the substrate I got from Lapland. He gave me the access and also provide the oyster seeds. The process is more or less similar to the previous scheme with bagasse. This time, I learned how to work independently and measure everything based on my knowledge and intuition.

Figure 8 All tools and preparation (left). Weighing the wool (center). Boiled the wool (right)

Figure 9 Oyster seeds (left). Mixing wool and mycelium (center). Temperature in the growing box (right)

Figure 10 Inside a dark chamber (top left). Growing mycelium (top center & right). In a growing chamber (bottom left). The pins are growing (bottom right)

Using the same seeds, I found that the growing part didn’t as fast as with bagasse substrate, but it somehow worked. It's very satisfying to see the mycelium develop into a fluffy cloud shape, and then slowly become a more refined skin mycelium layer. I always think the mycelium-growing skin is similar to tempeh, which also uses a type of fungus to ferment and bind into a cake form.

I intended to be able to see the mushroom body growing, but the progress was not visible, so I moved it to a larger box and placed it in the growing cabinet. The pins started to grow, however, I didn't realize that the cabinet was not connected to the humidifier, so it stopped the growing body. As a result, I had to abandon the mission.

However, I am quite satisfied that I can see the mycelium was growing. In the future, I will work carefully and provide a better environment for them to thrive and grow beautifully.

Mycelium Work: Working with Molding

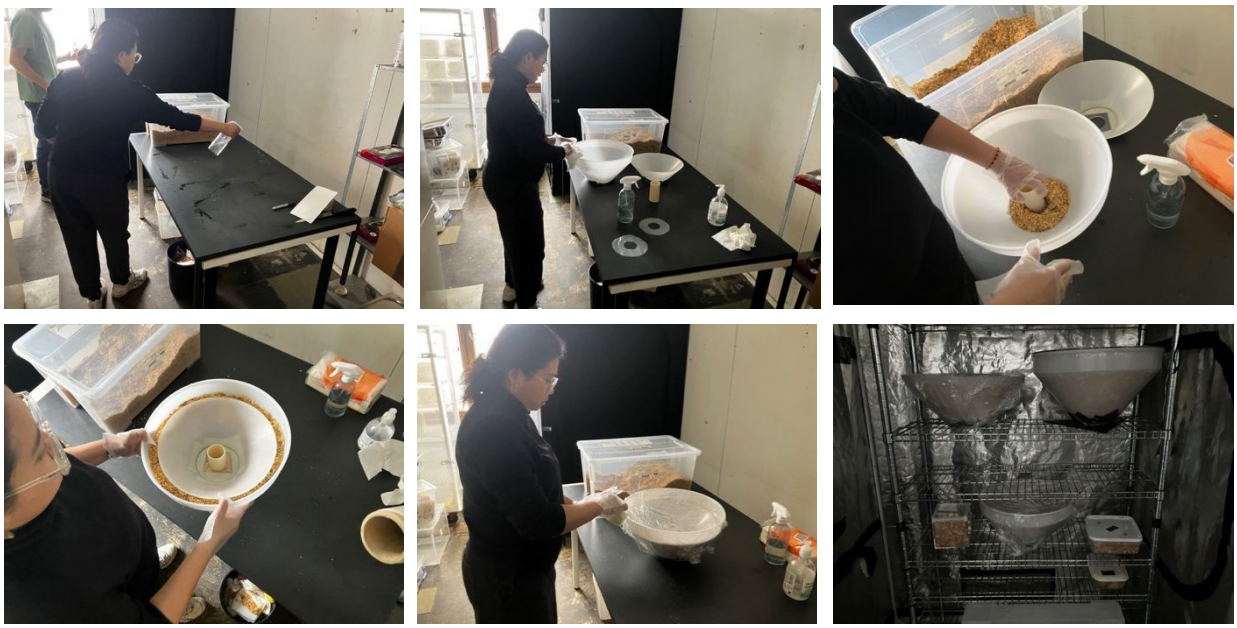


Figure 11 Create a lampshade from glow in the dark mycelium and wood chips substrate, with the mold technique.

Aleksi had a glow-in-the-dark mushroom seeds. Despite it is quite old stayed in a fridge, he decided to work with it. So, we planned to do three types of mycelium products. The images above showed the process of creating a lampshade with the help of a mold. There are two molds, an outer mold and an inner mold. Basically, after mixing all the ingredients, I put them in a mold. This mold functions as scaffolding, helping the mycelium to grow and at the same time compacting the contents. The processes are more or less the same, put it in a dark chamber and see how it grows. Unfortunately, because the seeds are quite old, contamination occurred and we had to stop this mission and throw them away.


Figure 12 Contamination occurred

Mycelium Work: Sausage Technique


Figure 13 Mycelium and wood chips substrate with 'sausage' technique

Another method for working with mycelium is through the sausage technique. All the materials are put into fabric like stockings, then shaped according to what we plan. The advantage of this technique is it does not require molding, but instead relies on the strength of the substrate itself. I didn't expect that soft materials like fabric could be made hard and strong with the help of mycelium.

Mycelium Work: Making Surface

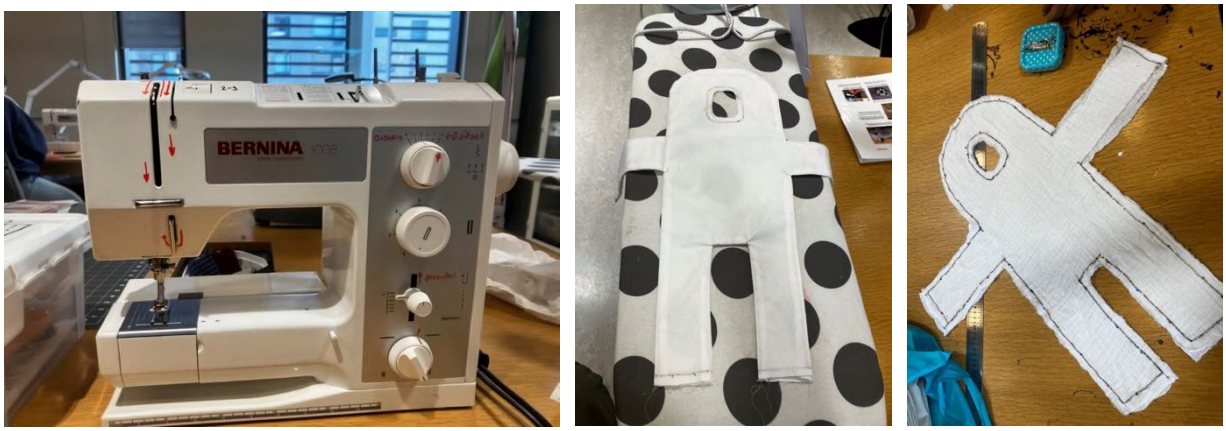


Figure 14 Making a surface skin of mycelium fabric sculpture

After two months have been working with Aleksi, he gave me flexibility to do my independent work, something that I can be responsible with the schedule and carry out the project by myself. I interested to work with fabric and mycelium, and he show me his future project to make a mycelium man, some sculpture made of fabric. His idea is to plant the mycelium with substrate inside the fabric sculpture. This was a great idea and have a connection to my interest to work with wool fabric and mycelium.

It always a good feeling when I try something new. From this project, I learned how to sew with the sewing machine for the first time. Unfortunately, after this sewing part is done, we didn't continue to grow the mycelium because the studio has been busy with other projects. However, as I learned a different technique on how to grow mycelium, I can plan something similar for my own project.

Mycelium Work personal Project: Making a Surface / Skin

After I got knowledge to make a fabric sculpture for mycelium, I make it for my own project. The idea is to put mycelium and raw wool inside of the fabric. I did some rough sketches for the shape ideas of the fabric skin. I deliberately choose the shape of a sheep that will grow a mycelium from its body. I think it was the perfect metaphor to

capture the idea of utilizing a wool bio-waste from industrial wool and embracing a new life of mushrooms.

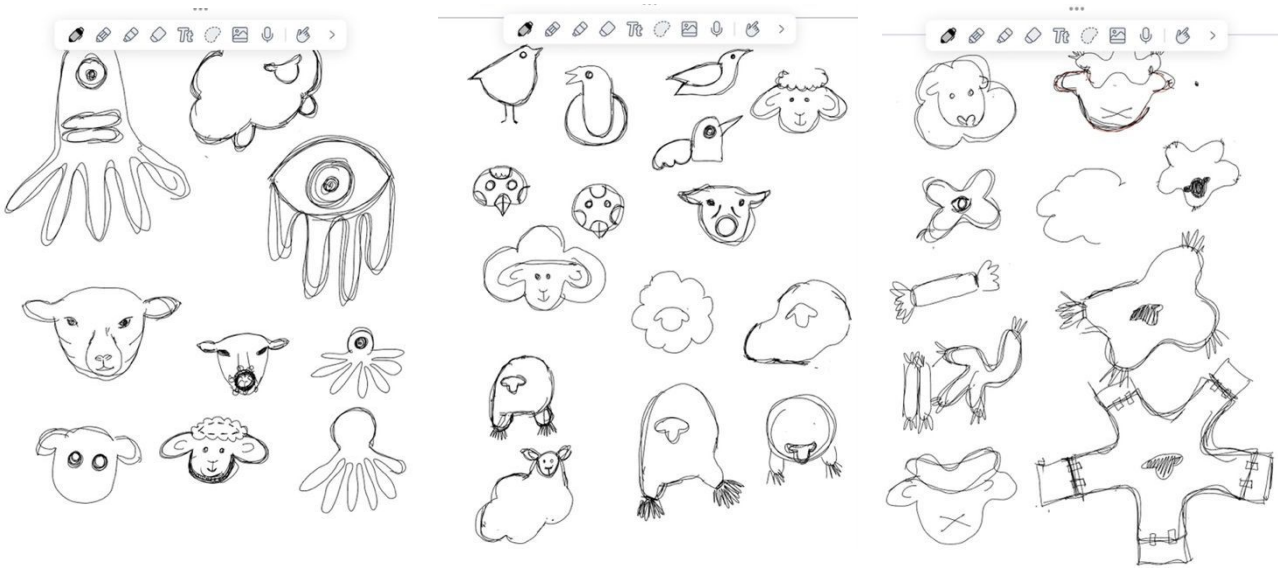


Figure 15 Sketches for mycelium sculpture (personal project)

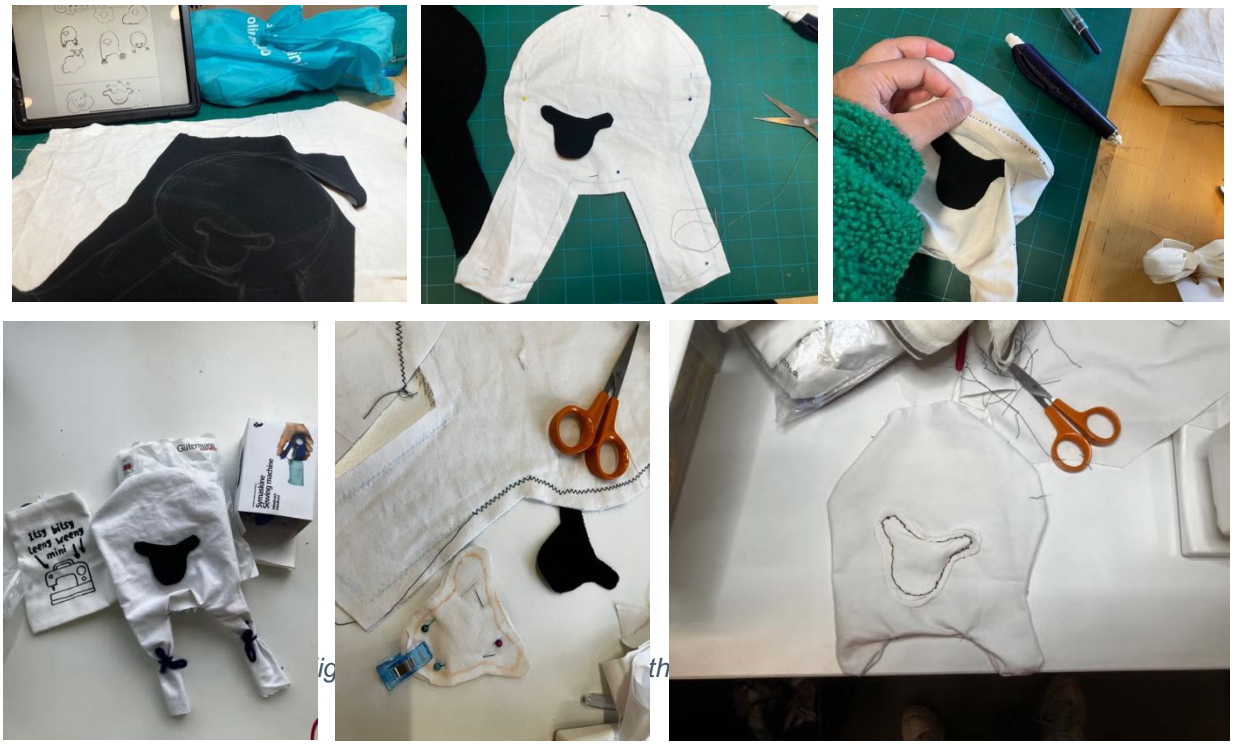


Figure 16 Process of making the sculpture skin fabric

Personal Project: Material sample from wool & organic glue

I was thinking to create other samples from the wool material. Since Aleksi had a leftover organic glue, it inspired me to mix the wool with it. Surprisingly, it was quite a challenge to mix the fibers with glue, as the fiber will stick to your hand and harder to make a balance between the two adjoining materials. As a result, I made two samples, one mixture I pressed with hydraulic press machine, while the other I just leave it to dry.

Figure 17 Step by step process into making a material made from organic glue and raw wool

Kombucha: Making a sheet

There was some SCOBY culture in the studio, and I handed a task to make a SCOBY sheet leather from it. First, I blended all the SCOBY together, remove some excess water as much as I can. Moving on, I lay the 2 cm and 1.5 cm thick sheets on the drying frame. It will gradually shrink while it's drying. This SCOBY sheet can be used as a replacement of leather, or plastic.

Figure 18 Making a kombucha sheet

Reused PLA material

Figure 19 Processing PLA with food dye colour

Once in a while, the studio processes the plastic waste and reuse it into a new material. They gathered all the plastic cups from Solstice festival. We shredded the plastic into a very small sizes and tried to color it with a food dye. We also tried coloring with natural dyes such as cloudberry and blackberry juice, but the color didn't last long.

An analysis of an individual function at the workplace and its examination from the perspective of studies

My experience at the workshop provided invaluable insights into the practical applications of sustainable design principles. From a study perspective, this internship offered a hands-on approach to learning, allowing me to bridge the gap between theoretical knowledge and practical application. It highlighted the significance of interdisciplinary thinking and the need for designers to consider environmental sustainability as a fundamental aspect of their work.

One of the highlights of my internship was the opportunity to contribute my own ideas to the workshop's projects. Specifically, I proposed a project involving the integration of discarded wool from Lapland with oyster seeds mycelium. This initiative allowed me to apply theoretical knowledge gained during my studies to a real-world scenario, demonstrating the practicality and potential of sustainable design solutions.

a report on possible acquired skills, views, and networks and an estimate of possible tasks after graduation

Through this traineeship, I have acquired a range of skills that will be beneficial in my future career. It underscored the importance of creativity, innovation, and a deep understanding of bio-material properties in implementing creative solutions. Additionally, I have developed a network of professionals who are leaders in the field of sustainable design, providing opportunities for collaboration and mentorship.

Upon graduation, I anticipate applying the skills and knowledge gained during my traineeship to pursue a career as a bio-designer and sustainable architect. I am particularly interested in roles that involve the development of eco-friendly products and installations, leveraging my experience with bio materials and sustainable design principles. I see myself contributing to the ongoing efforts to reduce our reliance on harmful materials and promote a circular economy, where waste is minimized, more

connectivity with living organisms, in order to create and provide valuable products and services.

Additionally, this traineeship equipped me not only with the acquired skills, but also how to navigate myself into the scenario of tactical entrepreneurship. This experience has opened my eye that to become a bio-designer, we could start making a project from simple and *DIY* tools, that easily accessible and assembled.

Appendix F

Living Wool: A Critical Reflection on Material, Time, and Care

This appendix contains the full report titled *Living Wool*, written as part of the IKK-Frit course *“Rocks, Fields, Seas, and Forests: Aesthetic and Cultural Engagements with Materiality during Climate Crisis”*, submitted on January 1, 2025. The report explores conceptual and ethical dimensions of working with living materials such as mycelium and wool, and reflects on themes of collaboration, control, and care within speculative design practices. It supports the artistic and material inquiries developed throughout this thesis.

The full text begins below.

Living *Wool*

FIAN ARRAFIANI

JANUARY 1, 2025

University of Copenhagen

Living *Wool*

FIAN ARRAFIANI
fpq869

4841-E24; IKK-Frit emne-Rocks, Fields. Seas, and Forests:
Aesthetic and Cultural Engagements with Materiality during Climate Crisis

January 1, 2025

All photos that are not cited are taken by the author

Content

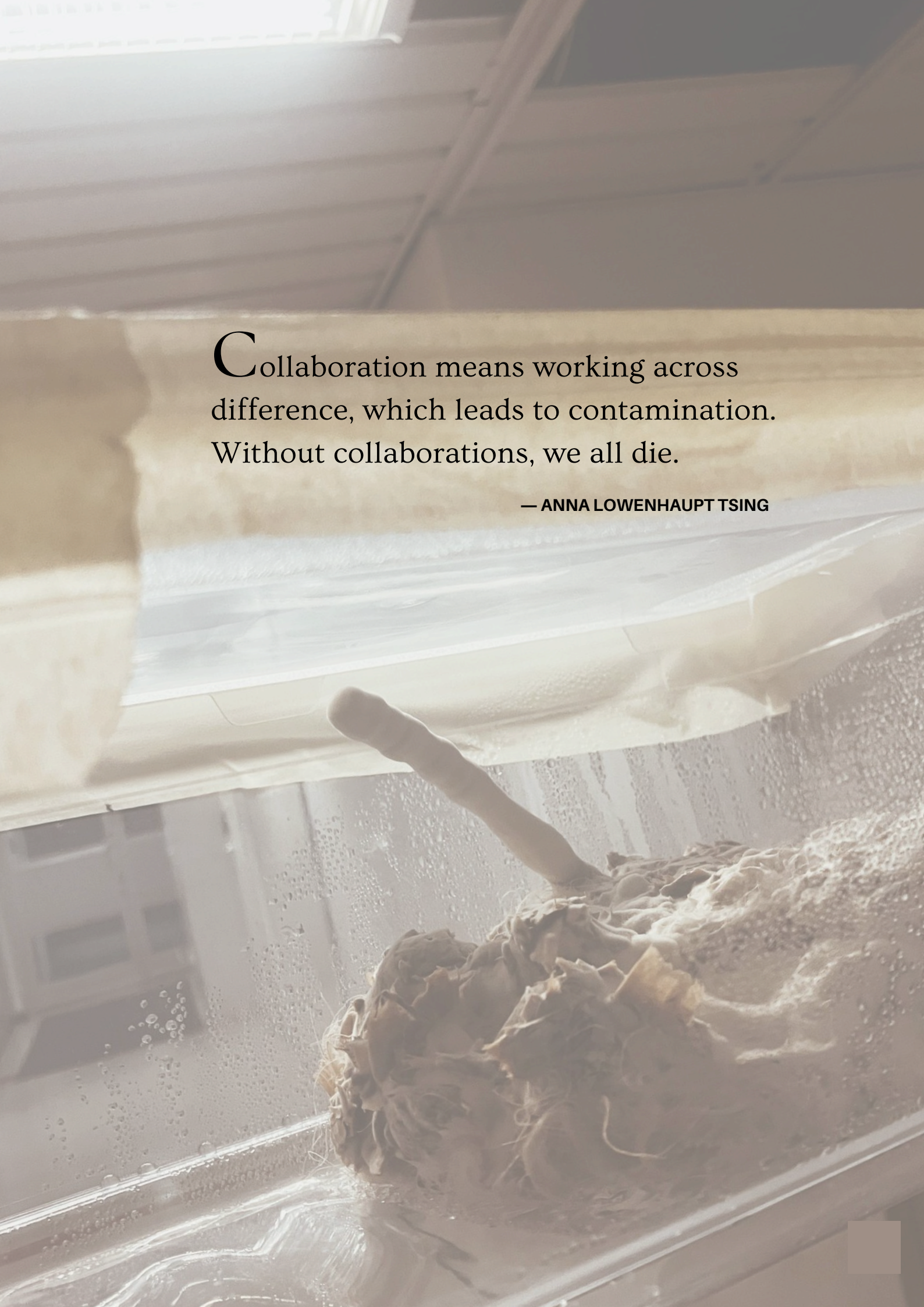
Foreword

The series of project combines wool craftsmanship with mycelium-based materials, motivating me to research a new material palette for designers and artists. In the making of these bio-material entities, I aim to transform my role as a designer from passive receiver to active maker and foster a creative process that collaborates between humans and living organisms. But over time, this practice sparks a critical reflection:

How is the relationship intertwined between me (human) and living organism (non-human) in the process?

What are the ethical considerations in domesticating living organisms?

In the search for the answer, I reflect on theories from Maria de la Bellacasa, Anna Tsing, Donna Harraway and many more.



Collaboration means working across difference, which leads to contamination. Without collaborations, we all die.

— ANNA LOWENHAUPT TSING

Myco-Doll

METAMOPHOSIS OF A LIVING REISHI MUSHROOM THAT IS TRAPPED INSIDE A SHEEP BODY. QUESTIONS ABOUT IDENTITY AND 'CONTAMINATION'.

Outer skin sewed cotton fabric

Inside Reishi (Ganoderma Lucidum) spawn with various organic substrates (raw wool from Lapland, oat, and wood chips)

Wool materials supported by VillaInno at the University of Lapland, mycelium spawns supported by Cocoon at Aalto University, Finland

Life in Cavities

A LIFE IN BETWEEN THE CAVITIES.
IDENTIFY MYCELIUM GROWTH IN A WOOL CROCHET.

A DIMSUM OF REISHI

A lifecycle of mycelium which grow and eventually die

Outer skin a pre-loved wool crochet & ice cream sticks

Inside Reishi (Ganoderma Lucidum) spawn with various organic substrates (raw wool from Lapland, oat, and wood chips)

Mycelium spawns supported by Cocoon at Aalto University, Finland

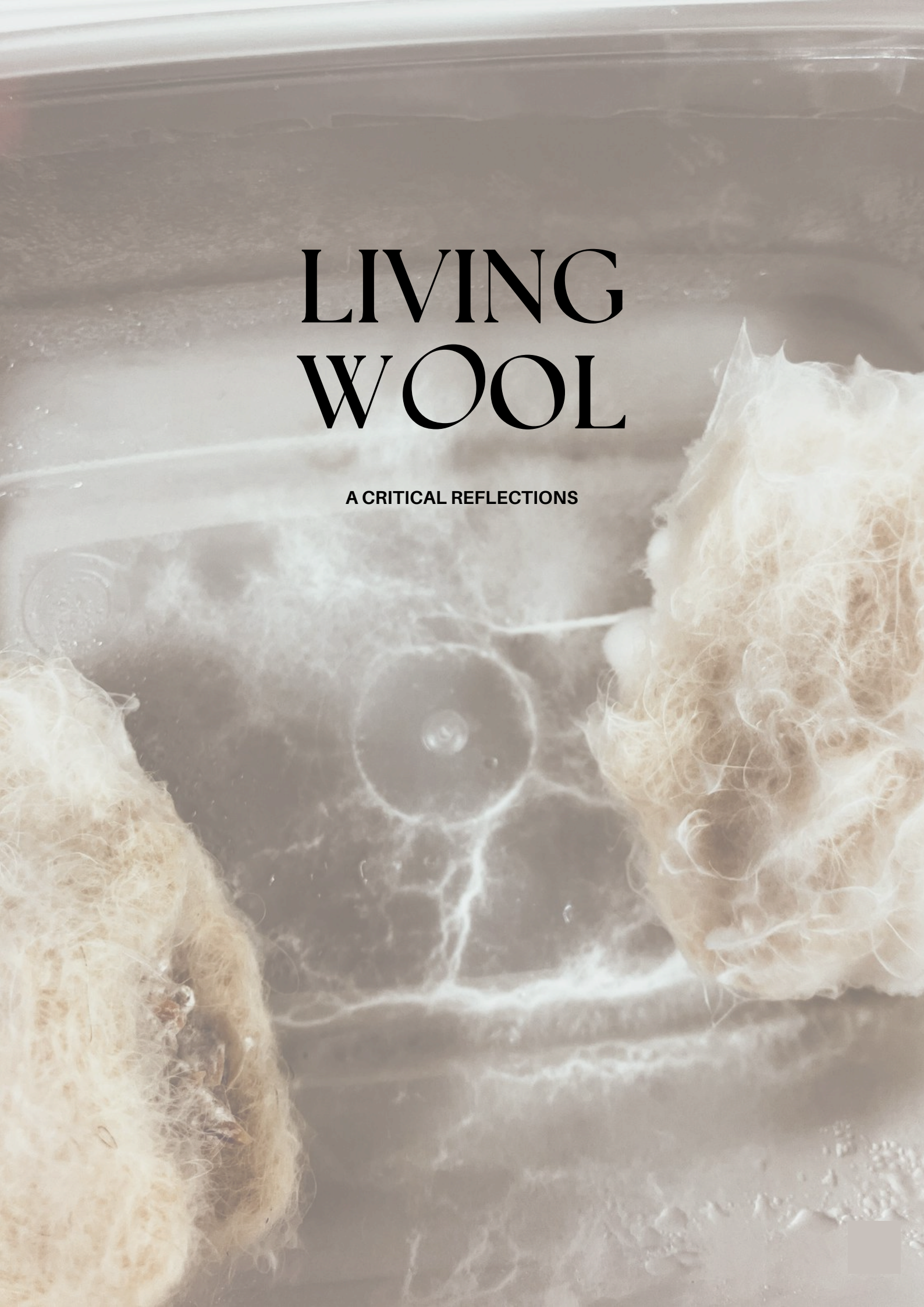
Wool-Scape

WHEN WOOL BECOME A LAND.
WHEN MUSHROOMS BECOME A COLONIZER.

Substrate A raw wool from Lapland

Spawn Oyster mushrooms (Pleurotus ostreatus)

Wool materials supported by VillaInno at the University of Lapland, mycelium spawns supported by Caracara Collective Studio, Finland



LIVING WOOL

A CRITICAL REFLECTIONS

A SECOND LIFE

Mushrooms. A tiny living organism sprouts everywhere in my studio—on the floor, on the walls. Every week, my colleague and I would scrape and discard them. It was irritating at the beginning. However, watching them reappear time and time again, I began to appreciate their incredible survival and resilience. Who would have thought that this tiny living organism, would bridge me to pursue my master's degree in sustainable art and design?

Mycelium. Also known as the roots network of fungi, it is easy to remember as the roots of mushrooms. An intricate mass branching of threads called hyphae. It uses organic substrates as its nutrients and to grow, binds the substrates together. Mycelium can grow on various kinds of organic substrates, which presents an amazing precedence to tackle the organic waste issue. What would be a perfect substrate for my mycelium experiment? Something that is deeply rooted in people in Finland, where I carried this project.

Wool. Traditionally, wool has been embedded in natives' people life for decades. A handspun of wool from sheep was used to create beautiful blankets and door covers by The Sámi people in their households (Koslin, 2010, p.6). In present times, many students in my class, both Finland and Copenhagen often do some wool crochet or knitting. It is remarkable how this practice has been passed on for generations.

Unfortunately, according to Stiles et al, wool production has significant waste issues. Only approximately 45% of the region's annual wool production is currently being marketed (with the remainder being stockpiled or discarded on the farm) (Stiles et al, 2012). That was how I found the perfect partner for my mycelium, a discarded wool.

As this writing is limited to a certain extent, I will be focused on the relationship I built in working with mycelium, a living organism that contributed to giving a second life of wool, a living wool.

A LIVING WOOL

Initially, working with living organisms felt like entering alien territory. They have their ways of growing—or not growing—and despite my attempts to control their environment, they still are unpredictable, for instance, where contamination appears unexpectedly. It reminds me of Tsing's description of precarity, a condition of being vulnerable to others. Unpredictable encounters transform us; we are not in control, even of ourselves (Tsing, 2015, p. 20). We can't rely on the status quo; everything is in flux. (Tsing, 2015, p. 20).

During a period of uncertainty and frustration, I attempted verbal communication with them. Sometimes, I begged them to behave, and other times, I exchanged small greetings. Was that kind of gesture that we—humans missed all the time? Indeterminacy—the unplanned nature of time—is frightening but also makes life possible (Tsing, 2015, p. 20).

Time. As a designer, I often work with measurable time. It is so unhinged that we call it a deadline, as a life—or—death situation. I don't know if this is even necessary. This term came from a modernization mindset and sparked criticisms. Tsing described that in a capitalism society, progress felt great; there was always something better ahead (Tsing, 2015, p. 24). De la Bellacasa argued that meaningful acts in the world of promissory capitalism involve taking risks and acting fast (de la Bellacasa, p. 174). This form of futurity creates an everyday experience of permanent precariousness: an ongoing sense of urgency and crisis calls us to act "now" (de la Bellacasa, p. 175). But how can I set the time to work with living organisms?

It is nearly impossible to schedule a time to work with mycelium. Its growth is deeply sensitive to environmental factors, including room temperature (25-27°C), good level of humidity, oxygen level, light exposure, substrate condition, human and other non-human interaction, and even their favorable soundscape. I am thinking of this project as an assemblage that Tsing mentioned, where the living wool is not just the combination of objects, but a dynamic interplay of conditions and relationships.

Care. Throughout this project, I was working across the time, a sense of the past (discarded wool), and an active present (mycelium and I). All aspects carried their own unique story, so much so that they needed special attention and care during the process. But what is care? Borrowing De la Bellacasa's concept of care with the soil, human-mycelium relations of care are also entangled. Modes of care have effects on what it becomes (de la Bellacasa, p. 170). That mode of care has shifted the focus from "how can we care more?" to examine what happens when we consider "how to care". (Bellacasa, 2017, introduction). Donna Harraway also had a similar notion in her concept of Staying with the Trouble. Working with mycelium didn't require such a relationship to the future, in fact, it requires learning to be truly present (Harraway, 2016).

ETHICS

I see people's reactions when they first hear about this new-provoking material. A revolutionary material that redefines our design practices, it is easy to get lost in this appraisal. As Crutzen put it, humans are guilty of the disturbance of nature in today's Anthropocene geological era. It made me question; How are the ethical considerations involved in domesticating living organisms?

Before I can try to answer, the first question I should ask is who will benefit from the discovery of this so-called revolution material?

It is quite a similar concept to biomimetic products designed “after nature” and end with radical “living”, intelligent, adaptive, self-maintaining, self-replicating structures (Chu 2004; Estevez 2009; Mathews, 2016, p. 11). In the end, it is still a product designed by humans exclusively for humans (Chu 2004; Estevez 2009; Mathews, 2016, p. 11).

I have thoughts similar to Miriam Josi’s, which convinced me that the project was collaborative. Still, in reality, I am the one who has the power to control the mycelium. I grow them in a laboratory instead of in nature, growing them inside a mold to shape them according to my desired outcome. At the end of the process, I can decide whether to grow the mycelium and kill it or let the mushroom’s fruiting body grow. Zheng Bo’s work of art of ‘Pteridophilia’ also provoked me. Why do I suddenly need to be concerned about ethical thinking in working with mycelium while eating mushrooms is morally accepted? How do I draw the line?

In search of the answer, I came to a research study by Mathews. Ethical considerations should be prioritized if there is an urgency to scale up the material to an industrial scale. Mathews proposed to adopt a bio-proportionality, where the goal would be to optimize the populations of all species relative only to the internal constraints imposed by the checks and balances inherent in ecosystems (Mathews, 2016, p. 15).

I don’t think anybody could have a definitive answer to this ethical question, nor should it have in the first place. However, as a human, it is always good to have this inner question in order to remain humble and not go too far.

FINAL WORDS

With all these modes of entanglement and complex collaboration processes, how was my role as a designer changing?

Borrowing Karana’s definition, it surely sparked the emergence of a new design practice at the intersection of design, materials science, biology, arts and crafts, which radically changes the role of the designer from a passive recipient to an active maker (Karana et al., 2015; Myers, 2012; Ribul, 2016; Rognoli, Bianchini, Maffei, & Karana, 2015).

The role of the designer is expanding, no longer limited to shaping existing materials but to creating and growing new ones. We become cultivators, manufacturing becomes 'horticulturing' (Collet, 2017, p. 27; Josi, 2021, p.36). A designer could also turn into an environmental manager if there is an urgency to scale up this material, a guardian responsible for checking the balances of ecosystems (Mathews, 2016, p. 15).

But let’s borrow Harraway’s concept of staying with the trouble, which is more considerable and spirited. It requires making odd-kin (Harraway, 2016, p.4) and I enjoy a kinship I made with mycelium by making a second life of wool. Let’s celebrate that for now.

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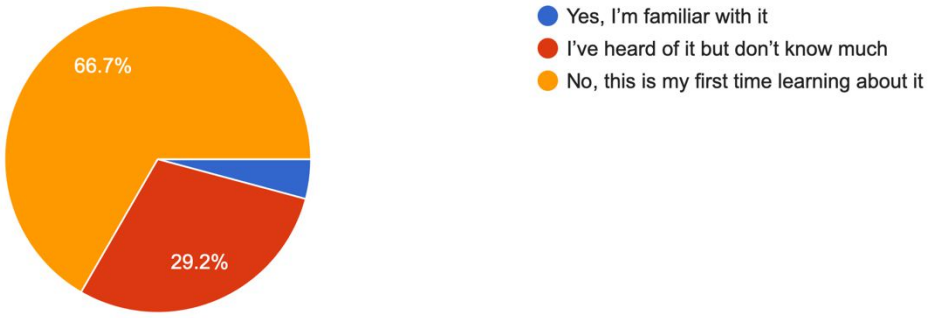
Appendix G

Living Wool Survey: Responses to Material Perception

This appendix presents the results of the first multiple-choice survey, completed by 24 participants, offering insights into how mycelium–wool composites were perceived by a general audience. While most respondents had limited prior knowledge of mycelium, many expressed interest in its potential as a sustainable alternative material. When introduced to its combination with wool, concerns emerged around safety, durability, and ethical considerations—particularly regarding the use of living organisms and animal-derived components.

Before visiting this exhibition, had you heard about using mycelium as a material?

24 responses



What is your first impression of using wool and mycelium together?

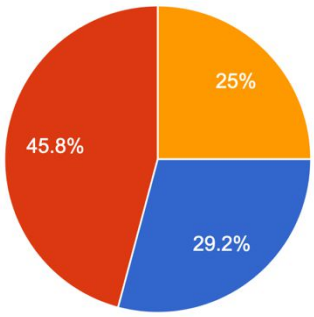
24 responses

What concerns, if any, do you have about using these materials?

24 responses

How do you feel about working with a living material like mycelium?

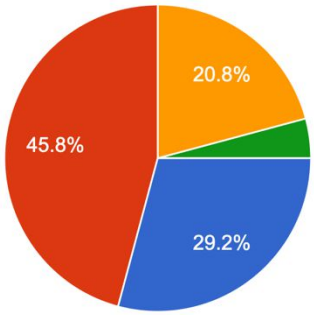
24 responses



- Exciting – It's like collaborating with nature
- Unusual – It challenges traditional ways of making things
- Unsettling – I'm not sure if I'd want to work with it
- Other (please share your thoughts):

Would you be interested in trying to create an artwork or craft using mycelium and wool?

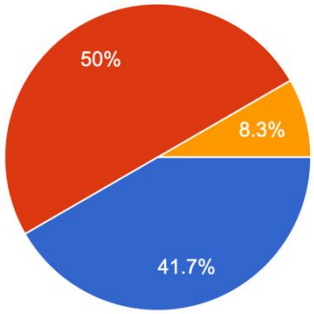
24 responses



- Yes, I'd love to experiment with it!
- Maybe, if I had the right tools or guidance
- No, it doesn't interest me
- Other (please share your thoughts):

Do you think this kind of material is suitable for the Arctic?

24 responses



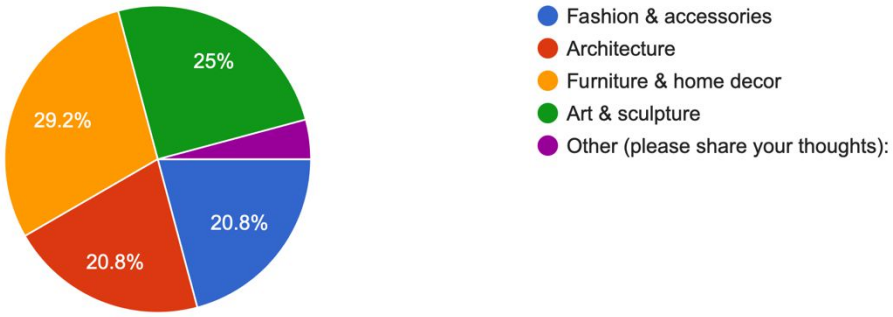
- Yes, it could provide insulation and adaptability
- Maybe, but it would need further testing
- No, I don't think it would withstand the extreme conditions
- Other (please share your thoughts):

Would you support scaling up this material for mass production?

24 responses

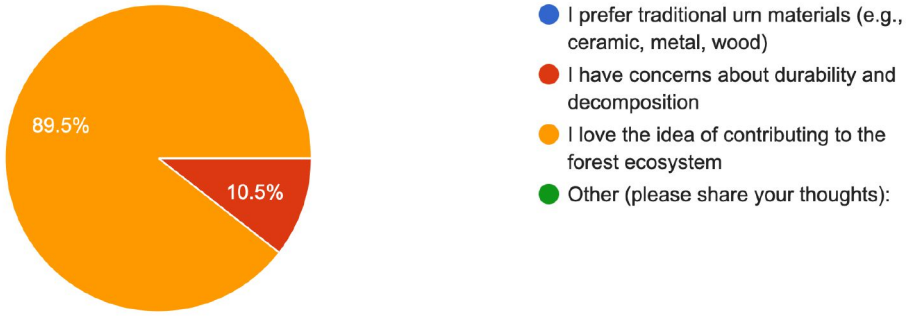
What kind of applications would you most like to see for this materials?

24 responses



What are your thoughts on a biodegradable urn made from wool and mycelium, designed to be planted in the soil—where the wool decomposes, an...unicate? (Image credit below: plantgrowsave.org)

19 responses



Appendix H

MDD Survey: Material Experience Reflection Responses

The second survey, conducted with three participants using an MDD approach, employed an open-ended format. Though small in scale, the responses offered rich sensorial and emotional insight. Participants described the mycelium–wool composites as both alien and familiar—soft yet crisp, strange yet inviting. They associated the materials with natural forms like clouds or textures such as tempeh. Emotionally, the materials evoked feelings of care, caution, and connections to future-making, reincarnation, and collaboration. These reflections suggest that unfamiliar bio-based materials can provoke meaningful engagement and metaphorical associations, resonating with the broader themes of this research.

What are these material reminds you of?

3 responses

What are the unique sensorial qualities of materials?

3 responses

tactile senses: crisp, spongy
The mycelium is soft
Textural (?) differences : soft, rough Solidity? firm, squishy, Sound?? Two of em creates cracking sound! Unfamiliar smell Alien like look! Somehow so familiar but also strange

What are the most and the least pleasing sensorial qualities of materials (according to you)?

3 responses

the most: light the least: crispy
Fragile
Raw look kind of scary(?)

Are the materials associated with any other material due to its similar aesthetics?

3 responses

like a crisp thin leather
Styrofoam and Tempe
Tempe- oncom (texture wise) Cloud? Kapuk? Sarang laba2 eh apa sih- nanti dijelasin pas interview aja.

How do you describe this materials? What kind of meanings does it evoke?

3 responses

Crisp and light. As for meanings i am thinking about reincarnation
Future material
Interest, Care, Collaboration.

Does it elicit any particular emotions—such as surprise, love, hate, fear, relaxation, etc.?

3 responses

Cautious
Relaxing
Belum ada ;)

How do you interact and behave with the materials?

3 responses

I interact gently and carefully as the material prone to breaks easily
Pleasing
Exploration mode!

What are your thoughts on a biodegradable urn made from wool and mycelium, designed to be planted in the soil—where the wool decomposes, an...unicate? (Image credit below: plantgrowsave.org)

3 responses