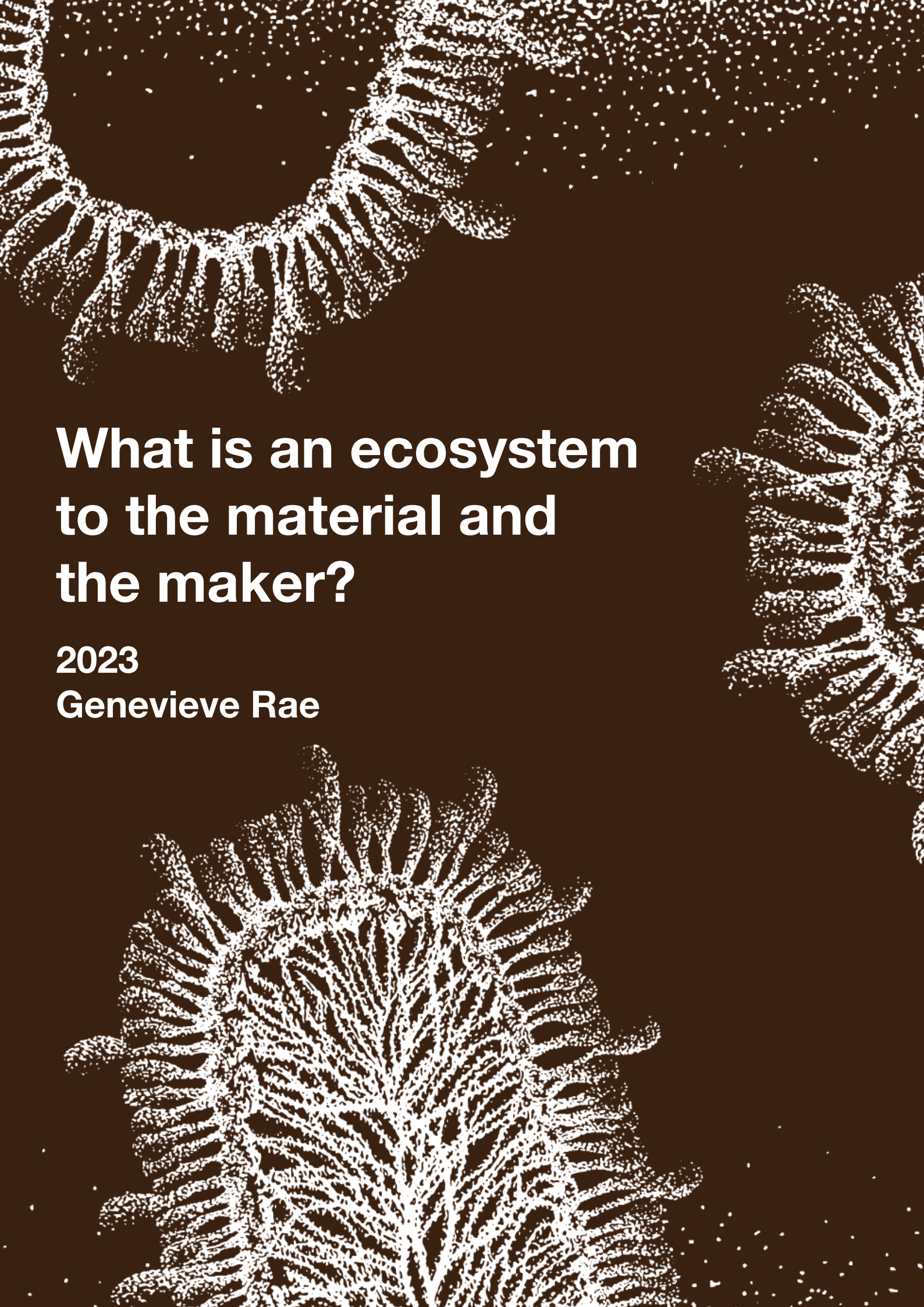

What is an ecosystem to the material and the maker?

2023

Genevieve Rae

What is an ecosystem to the material and the maker?

A thesis presented in partial fulfilment of the requirements for a Master in Design at Massey University, Wellington, New Zealand

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2023

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The ecosystems of Aotearoa.

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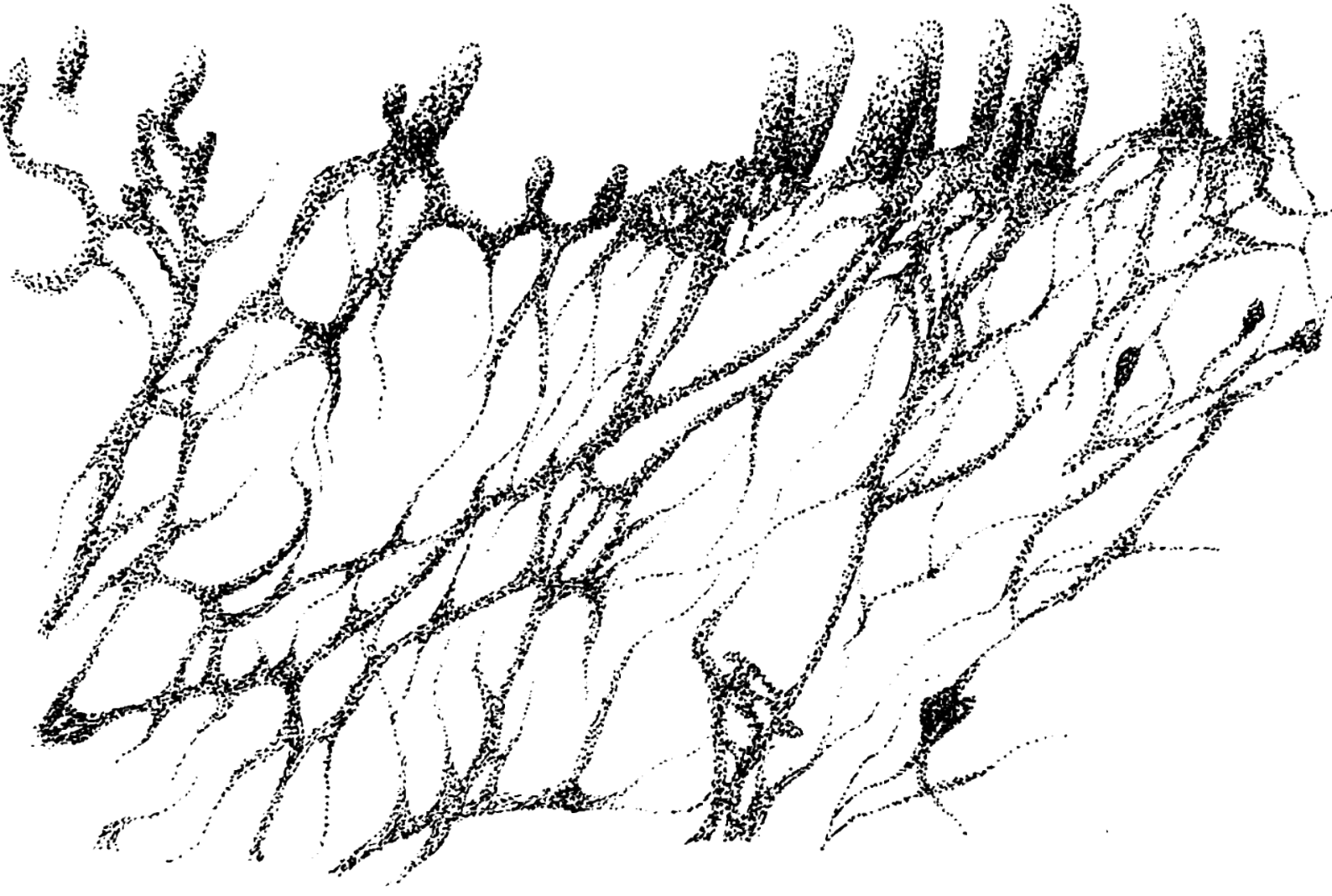
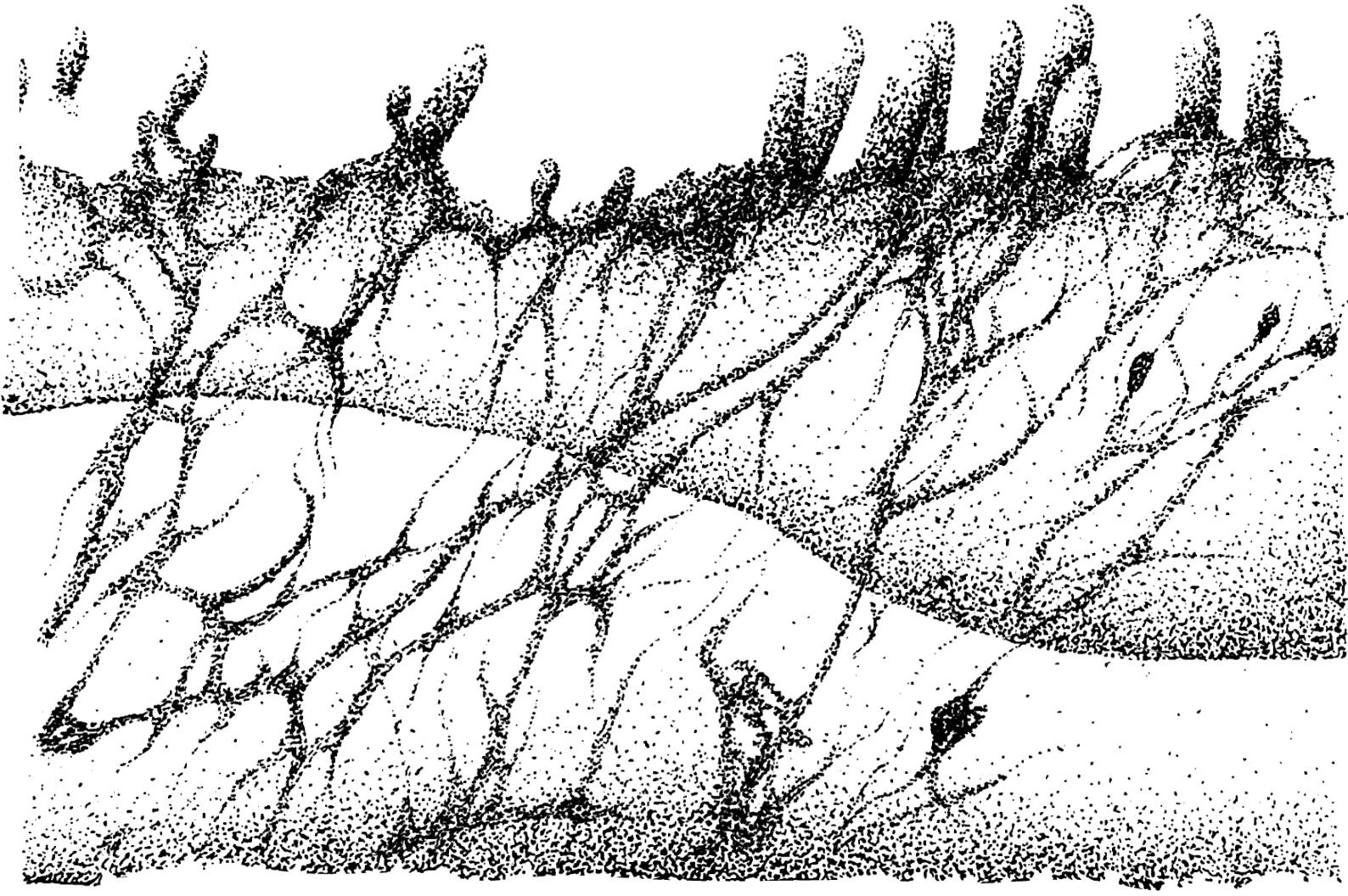


Abstract

Right now, the human-material relationship is strained, misunderstood, and destructive. This exegesis explores some of Aotearoa's human-material relationships and develops tools to design with in response. Through a multispecies philosophy lens, I investigate how designers might reposition themselves by considering materials design beyond human use in order to design more holistically. The project explores the creation of mycelium based materials and a practice of weaving in wild ecosystems. I will discuss systems that govern our human-nature relationships, the aspirations we have to achieve a circular economy, and aspects of well being that are woven into our environmental relations. Designers, across specialisation and disciplines, build our world, our physical and experiential surroundings. In order to do this ethically, as the custodial species, designers must listen to the terms set out by the land we design on and the ecosystems we design for. The outcomes of this project are offerings of tools and processes for approaching co-design with non-human organisms for the intention of designing in symbiosis with local ecosystems. This exegesis outlines my journey of making and unmaking with care and consideration for the inhabitants who share this place with us.



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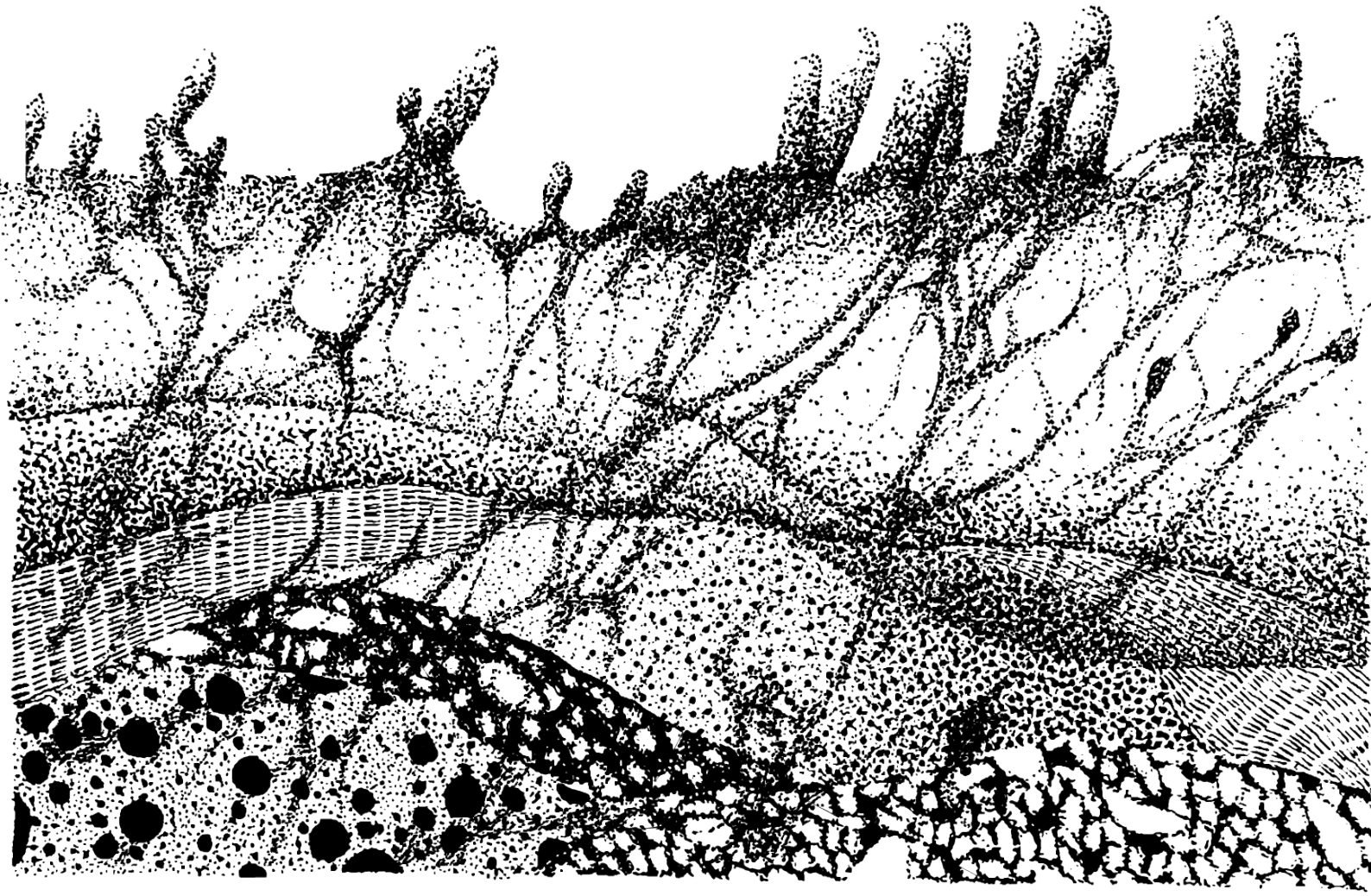


Key Terms

Material / Resource:
An entity of matter.

Relationship:
Repeated interactions between two or more entities of matter.

Ecosystem:
A web of relationships between entities in a localised area.

Nature/ natural:
Nature can be understood as everything, our surroundings and ourselves - all forms and beings on earth being intertwined within ecosystems. In this exegesis I hold this understanding throughout, but also use the terms nature and natural to refer to non-human dominated or ‘wild’ ecosystems.

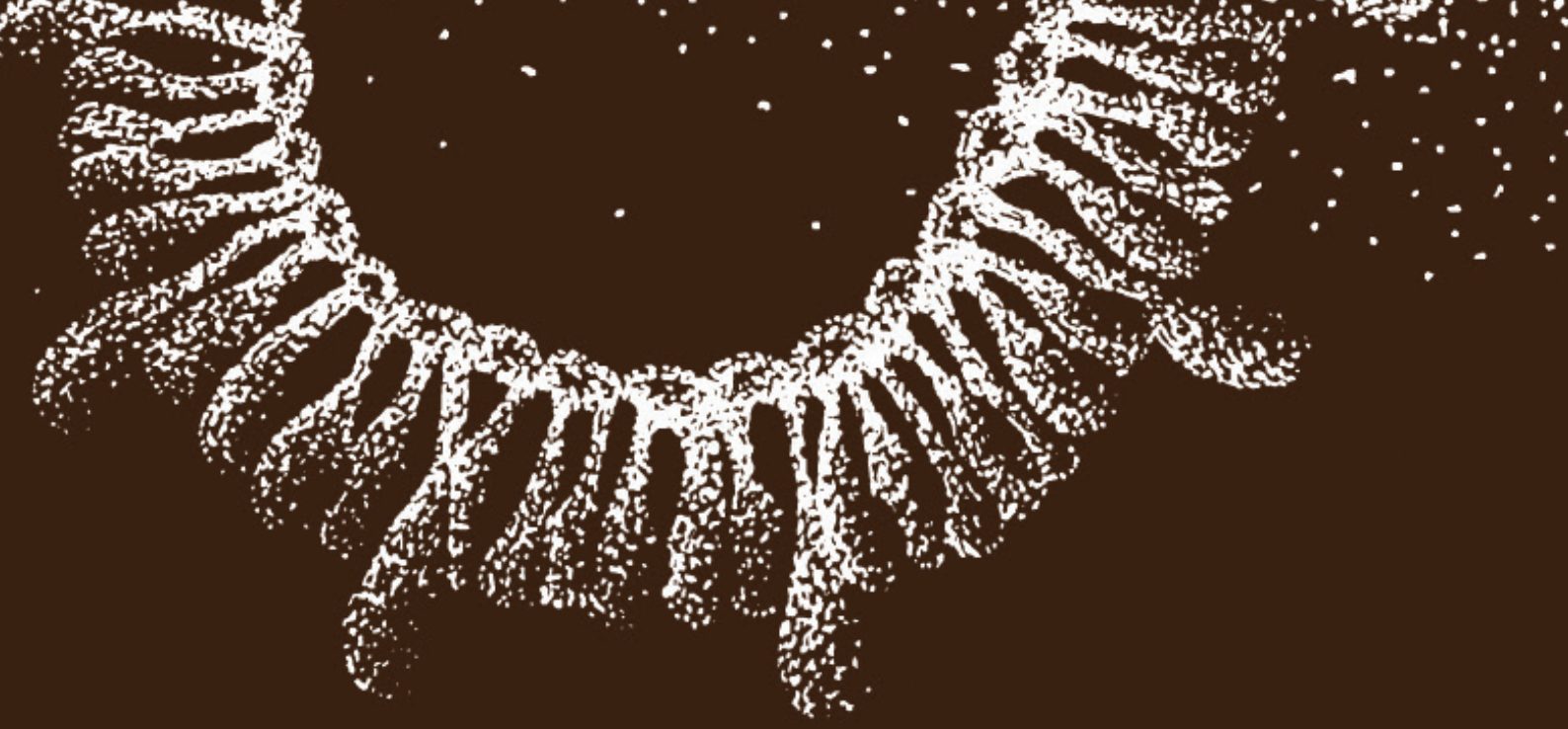
Wild:
Refers to ecosystems which are not controlled or organised by humans.

Well being:
Well being refers to moment to moment human experiences of wellness, mental health, sense of connectedness, and grounding in reality.

Sustainable; Sustainability:
This term has many definitions. In this exegesis sustainability refers to the longevity of human activities and processes in relation to their impacts on ecosystems.

Inhabitant(s):
Inhabitants are organisms which reside in an environment.

Inhabit; inhabited; inhabiting:
In this exegesis inhabit is employed to describe what is often referred to in mycology as ‘colonised’.



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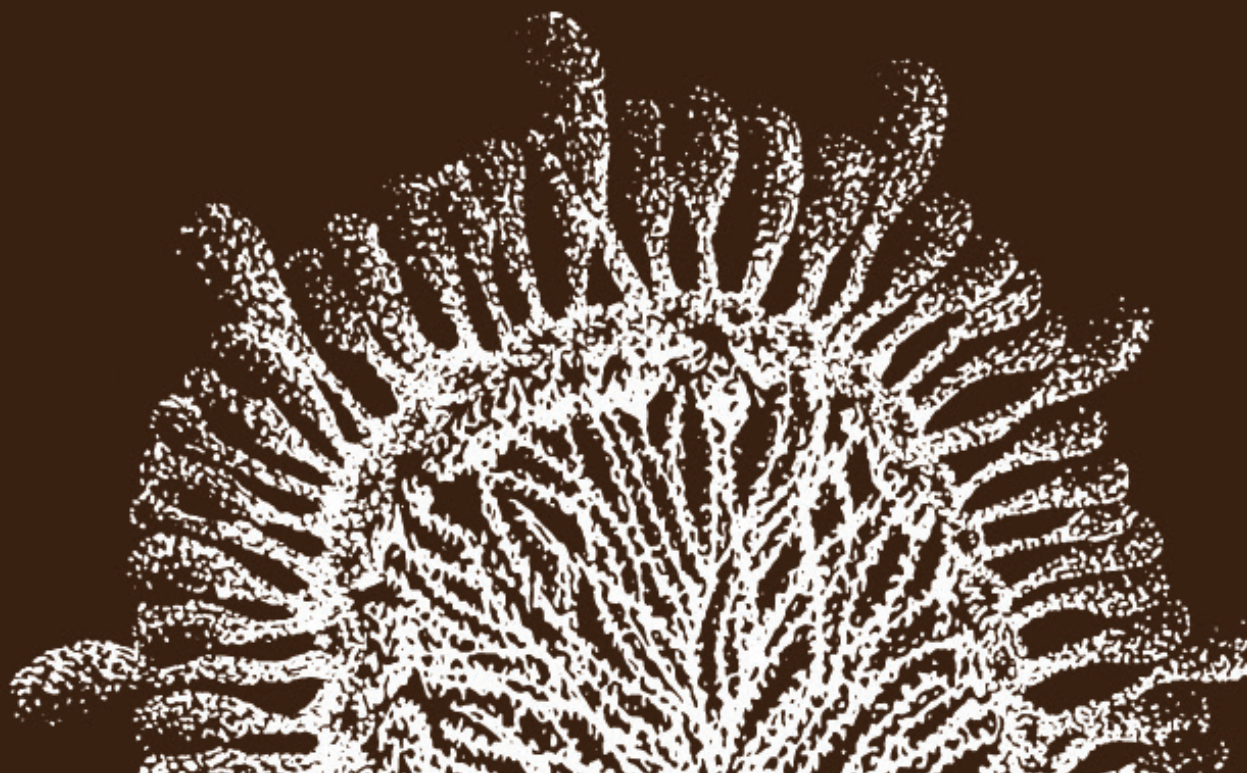
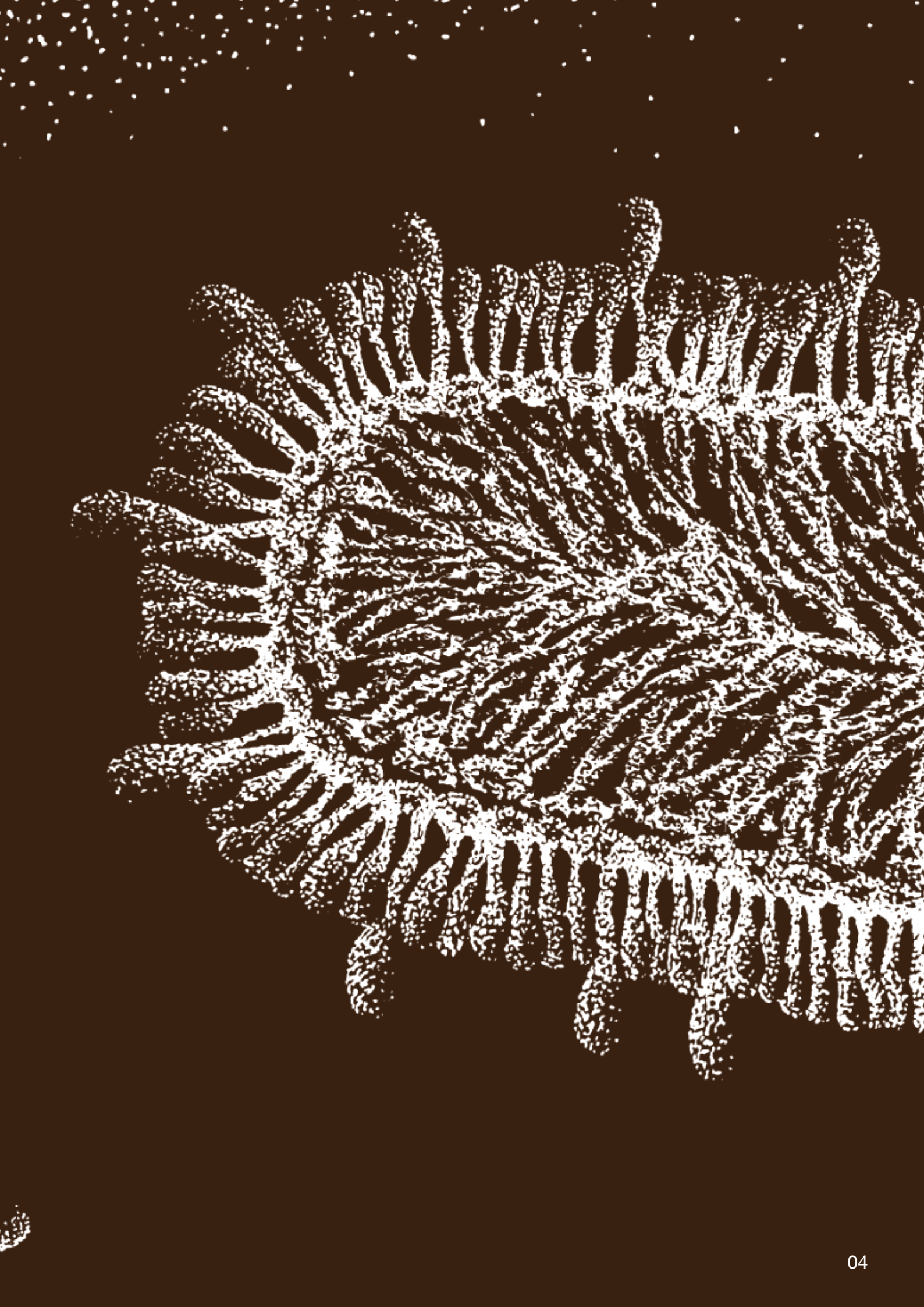




*We are practising multispecies philosophy while making textiles. We believe resources and materials are entities with a life force, all interconnected with each other, us, and te taiao. This is the journey *us-two are embarking on together, to explore the interconnection of our reality. Both physically, and metaphysically. Our guide on these travels are fungi. They teach us how to connect with those who are different from ourselves, in the way that mycorrhizal fungi connect the underworld of the forest, tree root to tree root. They also teach us to find life and love in death. In death our saprophytic friends make a feast, they celebrate, and invite in new life.*

*Us-two is a translation of the dual first person pronoun as articulated by Tyson Yunkaporta, in his book Sand Talk. Dual first person pronouns are common in Indigenous languages, but less so in English. The use of this term reflects Tyson's writing style; "to provoke thought rather than represent fact, in a kind of dialogical and reflective process with the reader," (Yunkaporta 22-23). This term recognises that as soon as we write knowledge it is already out of date and developed upon by the reader who will add their own meaning. As mentioned earlier, us-two are embarking on this journey together, you the reader are as much a part of this dialogue of knowledge as I am. To continue this relationship throughout the text I will use the terms we, our, us, or us-two, to remind us that we are both taking part in this experience.

“The real knowledge will keep moving in lands and Peoples, and I’ll move on with it. You’ll move on too,”

(Yunkaporta 20).

Right now, the human-material relationship is strained, misunderstood, and destructive. ‘What is an ecosystem to the material and the maker?’ explores some of the powers at play in Aotearoa’s human-material relationships and practical tools to design with in response. I will discuss laws and systems that govern our human-nature relations, our aspirations to achieve a circular economy, and aspects of well being that are woven into our environmental relations. Designers, across specialisation and disciplines, build our world, our physical and experiential surroundings. In order to do this ethically, as the custodial species, we must listen to the terms set out by the land we design on and the ecosystems we design for. I offer multispecies philosophy as a grounding concept to begin designing with care and consideration for the other species who share this place with us.

I am a feminine Pākehā tangata Tiriti, a person of European descent residing in Aotearoa under Te Tiriti o Waitangi (the Treaty of Waitangi). My identity has developed alongside people residing in my birthplace; Boonwurrung Country, Melbourne, Australia; to Ōtautahi, Christchurch, and to Te Whanganui-a-Tara, Wellington, Aotearoa. While studying a Bachelor of Textile Design at Massey University, I developed an interest in connection, and disconnection. Firstly, the disconnection between the textile industry and waste management systems was incredibly eye opening for me. The rate at which we industrially produce, consume, and waste low quality textiles is detrimental to our ecosystems and ourselves. During my undergraduate years I found connection with my peers very complex. Through a 200 level project I explored physical and metaphysical connection through skin and sensation. A 300 level project looked at the disconnection in Aotearoa’s young people, focusing on drinking culture, safety and vulnerability. At 400 level I created work intending to combat feelings of disconnect, and explore forms of connection through calming sensation and sentimental connection to jewellery. Throughout this time I explored many textile processes which has given me the confidence to play with alternative material processes such as mycelium materials. The embodied knowledge I hold allows me to design outside the box and fearlessly merge and develop processes. Over time I have realised that practising embodied textile knowledge improves my sense of well being and connection. My design interests have evolved into a focus on human-nature and human-material connections that create healthy ecosystems.

Spending time in ‘natural’ spaces has positive effects on our physical health, sense of well being, openness, and ability to connect with others (Lee and Lee; Mills et al.; Schebella et al.). Through this project we’re exploring how the embodied experience of creating materials - materials being our surroundings, clothing, and tools - allows us to better connect, and appreciate their impacts on ourselves and the environment as they go through their life cycle. So many of our belongings that exist today will outlive us by hundreds and thousands of years. Having a deeper understanding of the materials we own, their limitations, and abilities, allows us to dispose of them responsibly. Gaining an embodied experience of materials looks like learning to mend our own clothes, to fix our tools, to grow food, to have access to circular disposal systems, information and more. These things empower us to connect with our surroundings, and form connections that are beneficial for the wider ecosystem. The waste part of our ecosystem is ignored by many of us. Understandably so - it can be stinky, gross and remind us of death, and decay. Not taking care in the disposal of our posessions, especially at the design stage, has led our systems to become overloaded with unwanted matter. Most of us don’t know how our waste works, and we are not managing it well.

Aotearoa's waste and resource relationships

Currently in Aotearoa many of our communities take part in a linear resource economy (Fig. 1, left). In this system there is a disconnection between designers, materials, consumers, and the way natural ecosystems function. We extract, make goods, use goods, and waste goods. This is similar to the way we tell stories, there is a beginning, a middle, and a perceived end. The ending is where we become disconnected from the reality of materials and ecosystems. While landfill may be a short term economical solution, the long term environmental impacts are incredibly problematic (Perrot and Subiantoro 1). Once a material is in a landfill, it doesn't magically disappear. Our waste management systems allow us to ignore the realities of where our waste ends up and what the next stage of its life looks like. Our unwanted items lie in an almost eternal state, to be blown or washed away, causing havoc elsewhere. Regular and extreme weather can carry our solid waste out of landfills, littering both wild and human ecosystems. Alongside solid household and city waste, a large portion of organic waste ends up in landfills. It is estimated households in Aotearoa throw away more than 150,000 tonnes of food per year, which produces over 400,000 tonnes of carbon emissions (Diprose et al. 16). Due to the anaerobic environment, waste items which stay in landfills decompose slower than the human who claimed material ownership for a short time. To make change in these systems we need to be willing to engage with what we waste, and stop accepting waste generation as a necessary ingrained part of our production and consumption systems (Mirosa 1).

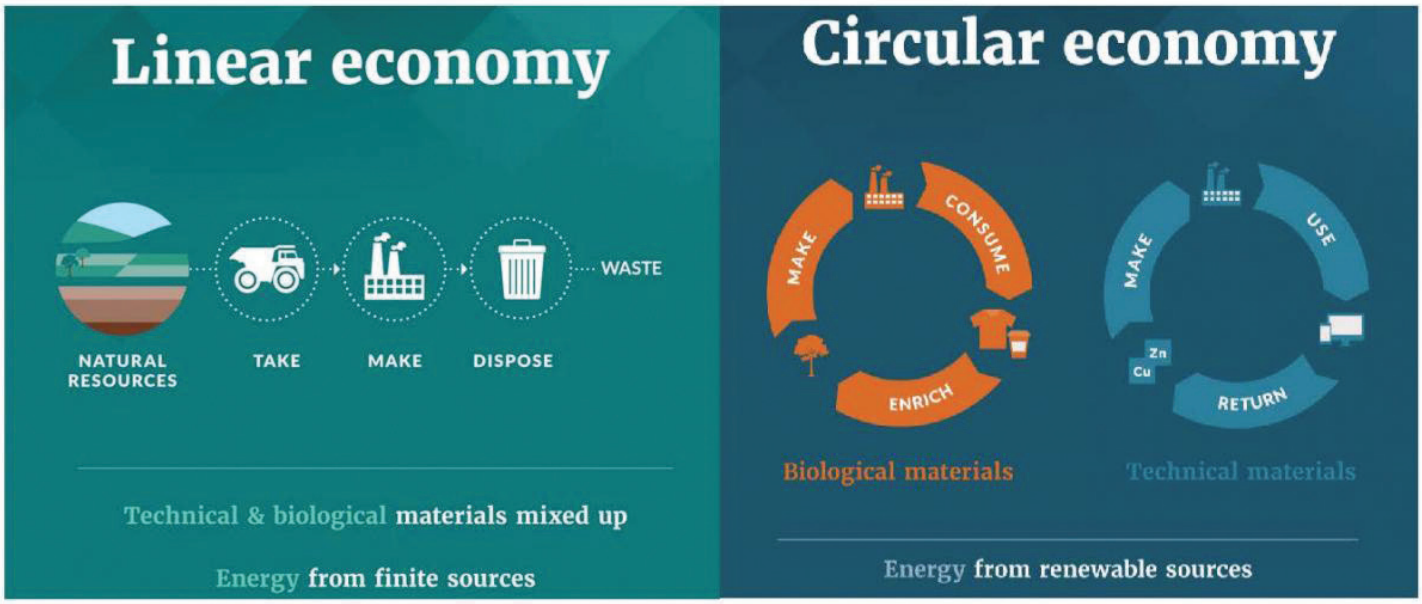


Fig. 1. Linear economy and circular economy comparison, 2022.

Aotearoa's government has committed to reforming the ways that we waste. Figure 2 is a diagram from a thirty year plan discussion document by Te Waihanga - The New Zealand Infrastructure Commission wish depicts the Waste Management Hierarchy in decreasing order of desirability. ReDesign is the most desirable waste management position in this system. This means designers need to be given power over how products are designed, and have the tools to design for a material's future, beyond its intended use. The design of a product directly influences the way a value chain will be managed, and up to 80% of sustainability impacts are decided at the product design stage (Bak-Andersen 8). A circular economy (Fig. 1, right) is a regenerative alternative to the extractive industrial model of a linear system. In this system materials and goods don't become waste. They are instead given value by being transferred or transformed for a new purpose. Designers have an important role in the move towards a circular economy. We are able to influence how, where, why products are created, and what we can do with them when they no longer fit their initial purpose. Following a multispecies philosophy framework is one way designers can begin to improve their practice and "ReDesign" for a circular economy.

Fig. 2. Waste minimization hierarchy and resource recovery and disposal infrastructure, 2020.

Introduction to multispecies philosophy

A multispecies design approach diverges from common methods of designing. An important aspect of multispecies design highlighted by Svenja Keune is an openness to a perspective that includes non-human inhabitants as beneficiaries. Keune has created a multispecies framework which "... refers to the intensity and inclusivity by which designers and other living beings engage with one another," (Keune 17). In chapter two we will investigate these levels of engagement in design approaches such as biomimicry, biodesign, mycorestoration, and practising multispecies perspectives. Throughout this text there are autobiographical reflections to assist in communicating the multispecies perspectives explored here. Through writing and voice memo, I observed relationships in my ecosystems and contemplated how my interactions with the ecosystem are part of a wider material web. In particular I contemplate the needs and experience of the fungi I work with in the lab, the insects and plants in my weaving environment, and the things that I learn from co-design events and interactions with non-human organisms. These reflections are mindfully scattered throughout this exegesis to support the reader's understanding of multispecies design thinking, and to illustrate the value of qualitative, open-minded, open-hearted reflection in design. This kind of design practice brings us closer to aligning with our local ecosystems.

Collaboration with other people is essential to this process. Each person holds a different perspective of experience and therefore their voice is valuable to the development of design processes and outcomes. Most fungal species are reliant on the presence of organisms of all kinds to survive in one ecosystem long term (Oyanedel et al. 3; Simard 192). Fungi do not work alone and neither should we. While an explicit interdisciplinary or collaborative design methodology has not been adopted as part of this work, the project is inherently interdisciplinary and organically collaborative as it is rooted in multispecies philosophy. There are a few examples of human collaboration throughout the project. Beginning with the dot work illustrations of fungi. These are pictured on the cover page and throughout the exegesis. They were designed in collaboration with a long time friend of mine Hannah Colenbrander, a designer and illustrator. As the lab ecosystem grows, Fin Georgeson (Industrial Design student), and Josef Belton (Spatial Design student) join us in co-designing mycelium materials, and together we reimagine processes and environments for growth. Developing materials processes from multiple perspectives broadens what is possible. Sharing knowledge, learning, and hearing different points of perspective is essential to creating ecosystems of symbiosis.

A multispecies philosophy approach not only benefits the organisms we rarely pay attention to, but also ourselves. What I have experienced is that approaching design with a holistic, ecosystem-centred mindset, has created a reciprocal positivity in my overall well being. An important aspect of practising multispecies philosophy is spending time observing, or being-with, a range of non-human species, many of which reside outside of buildings, homes, and other human spaces. In today's fast paced cities not many of us have the luxury of time nor access to natural spaces to be-with. This reality further disconnects us from understanding natural systems and where we fit into them, leaving most of us disconnected and many of us depressed. Time spent in natural spaces greatly increases a sense of well being and cognitive performance (Cassarino et al. 1; Wallner et al. 17). When humans have space and time to be in nature we are reminded of where our place is within natural systems. It is easier to see that we are inherently a part of nature, not inherently removed from it - even though we may live that way. Observing natural environments through a lens of multispecies philosophy grounds us in the understanding that everything on this earth has a life force, and each of these life forces are intertwined. When we can be at peace with our ecosystems and unafraid of non-human inhabitants, we can better interact with the undesirable parts of our resource systems - like waste.

Circular design systems

Alongside our physical disconnection from the natural environment is the disconnection of our economic systems from nature's systems. Circular economy is a complex idea defined in many different ways which has caused the term to become vague in meaning (Karell 19). It is a high level concept which places the activities of production and consumption of goods into the context of an interlinked ecosystem (Bak-Andersen 5; Casey 19-20; Karell 19-21; "Ōhanga āmiomio"). Like symbiotic relationships observed in nature. This is a very different approach to linear resource systems, in which we take virgin materials, make, and waste them, keeping most lines of production and consumption separate from each other (Casey and Johnston 4; Karell 13). Although as a society we approach the ecosystem with a linear mindset, our activities have always, and will always, be interlinked with one another - with the natural, and the unnatural ecosystems on earth (Yunkaporta 43-60). However, both designers and consumers within Aotearoa rarely have the tools or time to understand the connections between material, product, and where that product ends up once it is no longer in use. The material and production choices designers make have large impacts on the overall sustainability of a product. Consequently this obliges us to work on the level of both product and system if we are endeavouring to create in symbiosis (Bak-Andersen 9). In order to bend our linear systems into circular ones, we need to begin making small material connections and economic symbiotic relationships. Fungal mycelium materials are one potential route to exploring small changes within our existing systems.

Fungi and material relationships

Most of us know fungi as mushrooms. Mushrooms are the fruiting body of fungi, like a reproductive organ. These ‘fruits’ only form when conditions are right and the fungi is at a particular point in its life cycle (Stamets 12). Mycelium is a web-like network of living, individual cells called hyphae. Different fungal species’ life cycles can look slightly different. Generally, mycelium externally digests its surroundings by secreting acids and enzymes, which break down nutrients for them to absorb. This process is similar to our internal digestive system, just inside out. When it’s time to form a mushroom, the mycelium gather in a dense ball, called a primordia formation. From here the mushroom grows, matures, and releases its spore. These are the tiny little seeds, or eggs, that extend hyphae to meet with others of its kind, in the right conditions, and begin growing into a mycelium web again (Stamets 12). This cycle is illustrated in figure 3. In natural ecosystems, mycelium is often found under leaf litter, in decomposing logs, sometimes on dead insects, or animal manure.

In this project I develop relationships with the native phoenix oyster Pleurotus pulmonarius, and turkey tail Trametes versicolor fungi. These two fungi are saprophytic, also known as the decomposers (Stamets 19). The other known role of fungi, mycorrhizal - the plant connectors, are difficult for humans to cultivate as they are much more reliant on symbiotic forest relationships to survive (Stamets 26-27). This makes saprophytic fungi easier to work with in a controlled lab environment. The other reason these fungi are ideal for creating materials is because they happily consume many substrates that we consider waste. This means they are likely to help us design materials which valorise byproducts. This is a process of creating symbiotic interactions with non-human organisms to help us fulfil our daily needs in harmony with the ecosystem. Mycelium materials are a small chink of symbiosis in the wider ecosystem, and must be made and used correctly in order to benefit the system. Materials that are purely fungal mycelium and agricultural or wood waste are home compostable (Zeller and Zocher 53; “Mushroom Packaging”). They often add biodiversity and carbon to a compost, improving it. This ability to return to the ecosystem safely, easily, and directly via the user, fills what is usually a wide gap between material production and material disposal. This closes the material life cycle loop - an example of a circular system and a functioning, symbiotic, ecosystem.

In natural ecosystems saprophytic fungi play a very important role in the soil food web. As they absorb nutrients from organic matter, they grow into their food source. Slowly creeping throughout a log in a forest, for example. The mycelium creates channels for water to run through, and itself becomes food for nematodes and bacterias. These bacteria and nematodes are eaten by arthropods, protozoa, and earthworms who leave behind nutrient rich fluffy soil for plants, who are eaten by larger nematodes and arthropods, who are eaten by birds and animals. All these organisms are working in symbiosis to maintain a healthy ecosystem, by continuing the cycles of life and death.

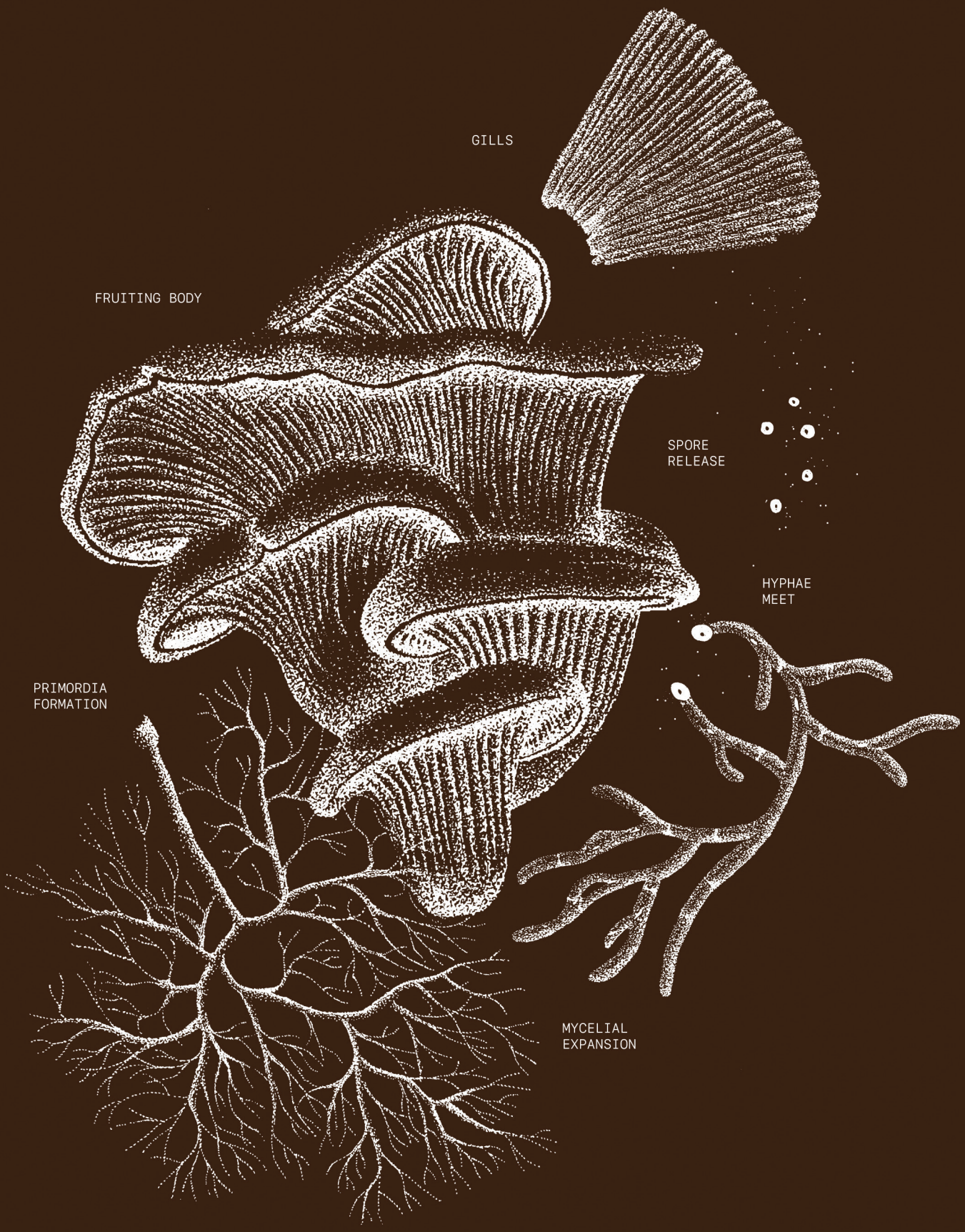


Fig. 3. Hannah Colenbrander and the author, Life cycle of the Pleurotus pulmonarius fungi, 2023.

Research question

What is an Ecosystem to the material and the maker?

Aim

The aim of this project is to evoke multispecies philosophy to improve materials design practice for a circular economy thus improving the well being of all ecosystem inhabitants.

Objective one

Explore the research question through a multispecies philosophy lens.

Objective two

Experiment with tools and processes that can help designers create circular material connections and symbiosis.

Objective three

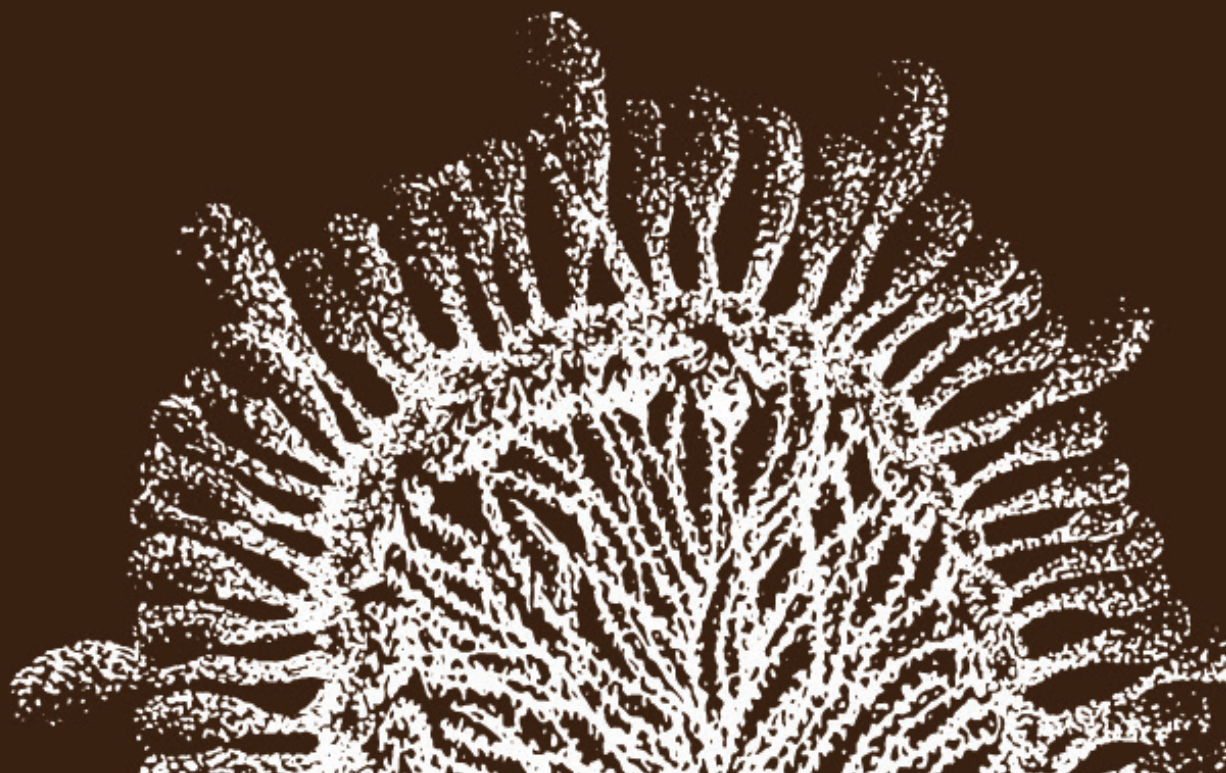
Communicate the process of designing mycelium materials.

“Nature does not separate materials from form, nor does science. In fact, one could go as far as to say that it is the material that drives the form in any living organism, and looking into an optical microscope will make it evident that the material already has a form,”
(Bak-Andersen 40).

Fig. 4. Photo by author, Turkey Tail mushrooms grown by the author, 2023.

Fig. 5. Photo by author, An oyster mushroom grown by the author, 2023.

02 Practicing Multispecies Philosophy



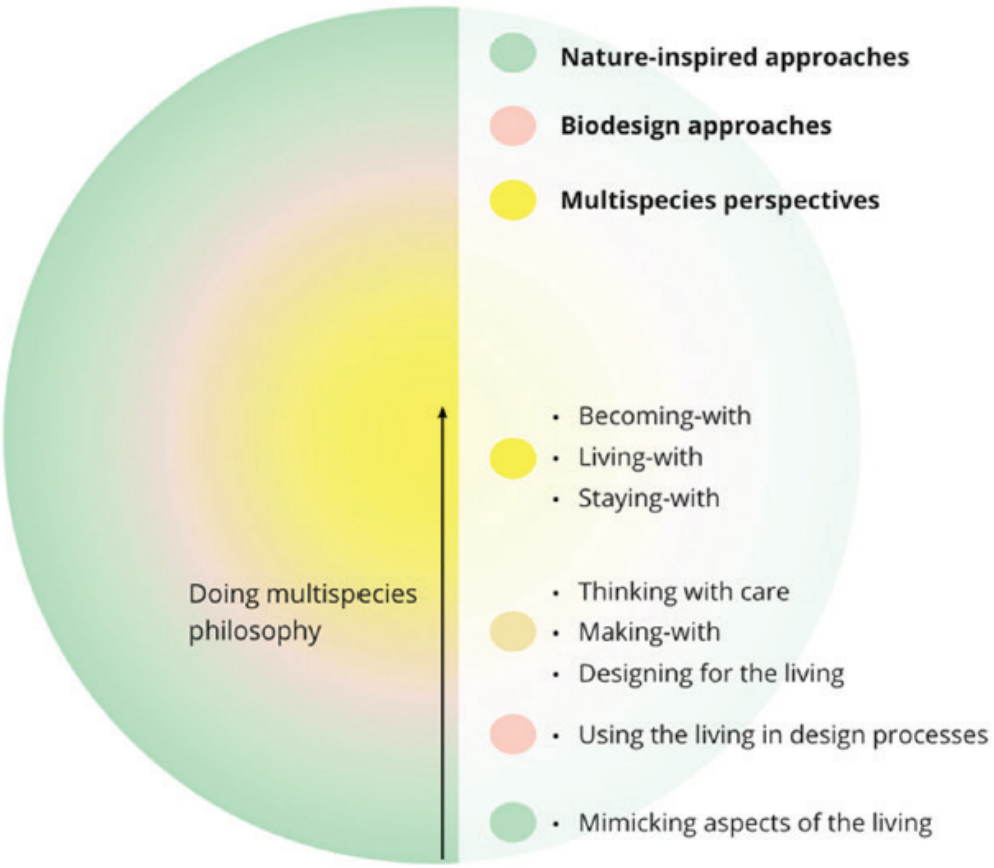


Fig. 6. Svenja Keune, A graphical representation of the conceptual framework that relates nature inspired approaches with biodesign and multispecies perspectives, 2021.

Multispecies philosophy is a concept I was introduced to via Svenja Keune's doctoral research. Her work explores textiles as mediators between people and our environments and she designs from a perspective that relates textile design to spatial design, horticulture, agriculture, permaculture and environmental philosophy. Keune advocates "for exploring more than anthropocentric and multispecies perspectives to textile design by understanding the textile design practice as a way of being-with and staying-with, rather than as a solution-driven practice," (2). In *Designing and Living with Organisms: Weaving Entangled Worlds as Doing Multispecies Philosophy*, Keune explores three textile multispecies events. A large group of lacewings decide to hibernate amongst woven tapestries. A caterpillar scales a hanging tapestry outside Svenja's greenhouse. A mouse family creates a home out of multiple tapestries, reforming them to suit their needs. None of these textiles were made with the intention for these interactions to occur. Each interaction with her work becomes part of the multispecies design process, and in each case the designer is presented with an opportunity to respond to or accept the other living organism's design choices (Keune 17-18). As seen in the multispecies framework, Svenja chooses to practise staying-with design events, and to care for the interactions with a curious mindset (17).

This chapter explores different levels of practising the Multispecies Philosophy Framework (Fig. 6) in textile and materials design, and how the closer we get to co-designing with multispecies perspectives, the closer we come to designing in symbiosis. The framework is a gradient directing us inwards. Three design approaches will be outlined in relation to four philosophical perspectives. We will look at some examples of 'Nature-inspired approaches' like biomimicry, 'Biodesign approaches' which lean into industrial production and consumption, design in conservation which begins to enter a 'Multispecies perspective', and finally explore what it means to design textiles by becoming-with, living-with, and staying-with. This is a useful framework to refer to as a way of understanding design events we engage with, whether they are initiated by humans or non-humans. These different points of perspective help us consider the depth of interconnection a design, or a design process, has within its ecosystem.

“The potential of an open-ended design event is to invite the not yet-known, to reach beyond exploring what can be already known, expected, assumed, or can be imagined. The textiles in the context of this work have a mediating agency,” (Keune, 17).

I am in a relationship with threads. We've been together for about 6 years now. Like all relationships, things are up and down, twisted, looped, don't get me started on knots. Regardless of the ins and outs, I love threads. They keep me grounded, they remind me to go with the flow. Threads are changing for me at the moment. Cotton, wool and the like are still in my life, but threads of fungal mycelium have come to shake things up. As I've been setting up the groundwork for my masters project, I wonder about the living organism I'm about to embark on this journey with. Are the mycelium here for adventure and innovation, or would they be more content living out their lives in the underworld of the ngāhere?

Nature inspired approaches: Biomimicry

Biomimicry is the design approach of mimicking aspects of biology. It is a nature inspired approach to designing, but it does not always benefit the natural environment. This is an important piece of well known brand Velcro's origin story. George de Mestral invented the fastening after noticing the way burdock burrs clung to his clothing and dog's fur. Inspired by this adhesion, he designed the hook & loop fasteners we know today as Velcro ("Our Story"). These are made of nylon, which is a very durable fossil-fuel based material, essentially plastic. While this nature inspired design revolutionised the footwear and apparel industry, consequences such as microplastics, and the disruptive industrial extraction and production of plastic fibres like nylon, has left mother nature feeling disrespected instead of deified. Of course this cannot be attributed solely to Velcro - nylon has been a popular fibre since we began commercially producing it in 1939. However, this begs the question of whether biomimicry should be commended as a design methodology on its own. Is it ok to take inspiration from nature only to become a detriment to it?

Biomimicry is not the inherent problem here, the concept is actually very important to human well being, and knowledge preservation. In his book Sand Talk, Tyson Yunkaporta shares indigenous ways of thinking with us by invoking images of sand talk, an Aboriginal custom of drawing images in the ground to convey knowledge. These images often reflect natural patterns which can be found throughout physical and metaphysical experience. An example of this is a symbol representing the First Law of creation, which 'mimics' the form of a flower (Yunkaporta 43). Three circles inside one another are surrounded by 'petals'. This represents a sustainable system in which the outer circle constantly becomes the inner circle, "expanding and contracting, rolling in on themselves over and over and reproducing in an infinite, stable pattern. This is a sustainable system," (Yunkaporta 45). The First Law is that nothing is created or destroyed, it only transforms. Creation is constantly in motion, and as the custodial species we must move and transform with it (Yunkaporta 43-60).

In this same chapter Yunkaporta critiques the western perspective of creation law - linear time. This stems from Aristotle's idea that the end (telos) is the principle of change, that everything must have a beginning, middle, and end. This concept is where our expectation of infinite growth, and inevitable annihilation, stems from. Yunkaporta takes us further through this idea to the foundational civilising mythology of ouroboros - the snake eating its tail - a representation of infinity (52). This is a phenomenon that physically occurs, often enacted by snakes kept in captivity. He critiques the image as holding the same linear curse, posing the question "how can this serpent be a symbol of infinity if it will eventually eat itself?" (Yunkaporta 52). The answer is that the snake cannot eat itself. There becomes a point where the snake dies, decomposes, and continues to be a part of the greater whole. We become misguided when we take small parts of creation law and apply those parts elsewhere. This is where biomimicry goes wrong. When we take the way a burdock burr clings to fibres and recreate it in plastic, we are ignoring the fact that a burdock burr is a seed trying to find a place to root down and be part of a system. A burdock burr is systemically interconnected with its environment by the plant's natural ability to decompose. Velcro is not.

Biodesign approaches

Like the burdock burr and snakes, we humans are beholden to numerous interconnected relationships across the earth ecosystem. Designers hold a large portion of resource transformations in their hands. We can think of these interactions as symbiosis. Hom and Penn define symbiosis as “the shared genetic fate of two or more organisms via physical association,” (240). Our contemporary survival relies on relationships with food and resource producing plants, pets and livestock, pollinating bugs like mosquitoes and bees, and the many microbes that live on and inside our bodies. Unfortunately, at this point in time, our activity is often parasitic and destructive to the complex relationships that make up our ecosystems. As the immediacy of these effects is becoming more recognised and accepted, biodesign approaches are beginning to scratch the surface of what it means to design for physical reality, not a vacuum. Biodesign in textile and materials design is an approach which engages with biology or biological processes to create what is often described as collaborations with the living. However, the environments made for organisms by bio designers are often only used to carry out a specific task or part of the organism’s life cycle. After the desired design outcome is reached, they are often killed (Keune 1). This is an anthropocentric, human centred, approach.

Biodesign is an approach which employs biology as a material or biological processes in design. Mycelium materials are an example of this approach. Their low environmental impact is making fungi materials the latest miracle material in the sustainable design space. The naturally polymeric, large celled, structure of mycelium hyphae make them ideal substitutes for fossil fuel derived materials like polyesters. Alongside their structure, fungi are known to consume what most other organisms might consider waste. Saprophytic fungi, the decomposers, forage for their food along the forest floor. Material designers can work like this too, creating-with materials that most people consider waste. This design lens can initiate circular material systems. BioFab, based in Tāmaki Makaurau, is a company working with Ecovative Design to manufacture Mushroom™ Packaging (“BioFab”). They grow mycelium materials in custom packaging moulds. Their products often replace the use of polystyrene. Materials such as polystyrene, and other petroleum derived synthetics, have detrimental effects to ecosystems throughout their existence (Zeller and Zocher 51). Materials like Mushroom™ Packaging are comparatively low impact to produce, make use of agricultural waste, and are home compostable. This could be a sustainable symbiotic relationship between fungi and humans.

Designers need tools and interdisciplinary collaboration to remake byproducts into things our ecosystems need, or to reduce systemic human waste. Hemp is a great source of nutrients for many saprophytic fungi species and is commonly used by mushroom growers. I got in touch with Hemp Connect who supplied me with hemp husk, a byproduct of the hemp foods production process. The mycelium and hemp material outcomes are similar to materials already found on the mycelium material market as replacements for polystyrene based protective packaging. Working with byproducts for materials links them back into the economic ecosystem, and the natural ecosystem. Utilising biodesign approaches to repurpose byproducts is a step towards designing materials that are interconnected with natural systems. The transition to mass producing mycelium materials instead of polymers like polystyrene is slow, and unfortunately on this journey we are likely to fall into the trap of removing desirable parts from a greater whole.

Designing for the living, making-with, thinking-with-care: Conservation

Bioremediation refers to designing a human response to an unhealthy ecosystem as a remedy to return the ecosystem to health. Conservation work is often inexplicitly underpinned by a multispecies approach - to conserve desirable symbiotic relationships between many different species. Mycoremediation is a process in which humans and fungi work together in conservation efforts (Rhodes; Das et al.; Bhatnagar et al.). This idea may seem removed from traditional design approaches, however the problem-solving aspects of bio and mycoremediation weave together designing for the living, making-with, and thinking with care, to form solutions. Fungi are essential to the soil food web (Rhodes 196), a complex balance of life that we rarely see. Underground, the diversity of microorganisms and the composition of soil in a localised area, impacts the well being of plants, and what kinds of plants can grow there. The activity of mycoremediation is to introduce fungi into an unhealthy ecosystem, responsibly. Ecosystems across the world are so diverse, and can be susceptible to introduced species. Therefore it is important to know the impacts of fungi that are already present in a local ecosystem, as they are often the best candidates for remediation. This is because they will support symbiotic relationships with other local organisms, impacting a whole web of interconnected life. Although this approach is very ecosystem-aware, there are still risks of throwing the system into further imbalance if we are not careful.

However ecosystems which are beyond repair due to human actions have been revitalised with the introduction of fungi. Stamets contributed to experiments in which phoenix oyster mycelium was introduced to a pile of oil-spill contaminated soil. After a few weeks the pile was covered in large, happy, oyster mushrooms. When the mushrooms began to decay, other life followed. Insects and worms brought birds and animals, who brought seeds. After a few months the once barren soil was teeming with flora, fauna, and funga (Stamets 91-93). Because of the damage we have already caused to the biodiversity of ecosystems which existed before our dominance, city, and population growth, ecosystems may never regrow into what they once were. We may never be able to give the earth the same amount of wild space it once had. If we are to nurture and live-with multiple species we may have to accept new, different ecosystems. In our cities, homes, rural areas, and forests. Designers play a very important role in how human civilisation moves into symbiosis with the other organisms we rely on.

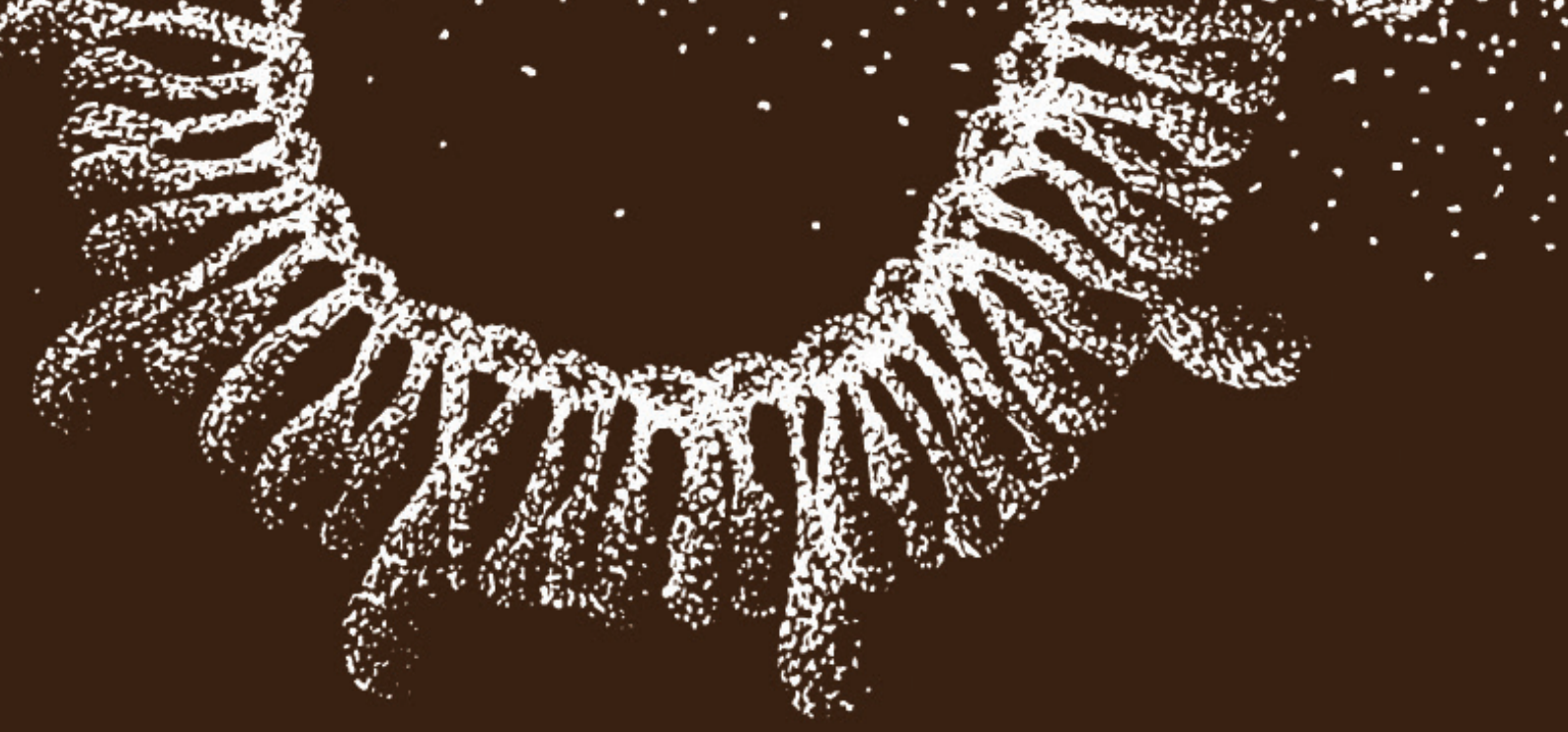
Becoming-with, living-with, staying-with: Multispecies Perspectives

This is where the concept of becoming-with, living-with, staying-with becomes important. If humans making decisions to act within an ecosystem do so without having spent time observing, understanding, and connecting with the ecosystem, they are not properly equipped to make decisions for that place. Doing so is dangerous because we are likely to take part in similar processes to what was discussed in Biomimicry and Biodesign. We will take knowledge we hold from experiences elsewhere and apply it to a place it does not belong. Keune notes that we often make decisions based on comfort and discomfort, whereas for other species inhabiting the ecosystem, our actions can mean life or death (16). She offers us the fundamental aspects of being-with, living-with, and staying-with. This means alongside time spent, and observation, we need "to stay-with the situation at hand and to care for it with an open and curious mindset,"(Keune 17). As I began working on mycelium materials in a lab environment, I quickly realised that the production of mycelium materials for commercial use directly contradicts this idea. The trouble brought on by moulds and fruit flies greatly affect the growth of mycelium and production of commercially viable mycelium materials. While material explorations in this project are not explicitly to produce commercial materials, in a scaled up commercial setting, contamination would not be tolerated and designers could not justify staying-with contaminants - we would likely create systems to keep contaminants out. An inherently human-centred process. This led me to explore a wild staying-with practice by creating a woven structure outdoors where I could practise approaching design with an open mindset towards the organisms who decided to weave with me. Spiders have taken a great interest in adding their webs to the tapestry, alongside bugs laying their eggs on wool, and mosses finding dark damp spots to grow on the warp. This practise of open ended collaboration feeds back into materials design in the lab. It is interesting to be designing in such juxtaposing environments. One which is so strongly human-centred, and one which is so open to interaction with other species. This experience shows me how misaligned our contemporary design approaches can be from the needs of natural ecosystems. As both ecosystems grow, the processes enacted there develop.

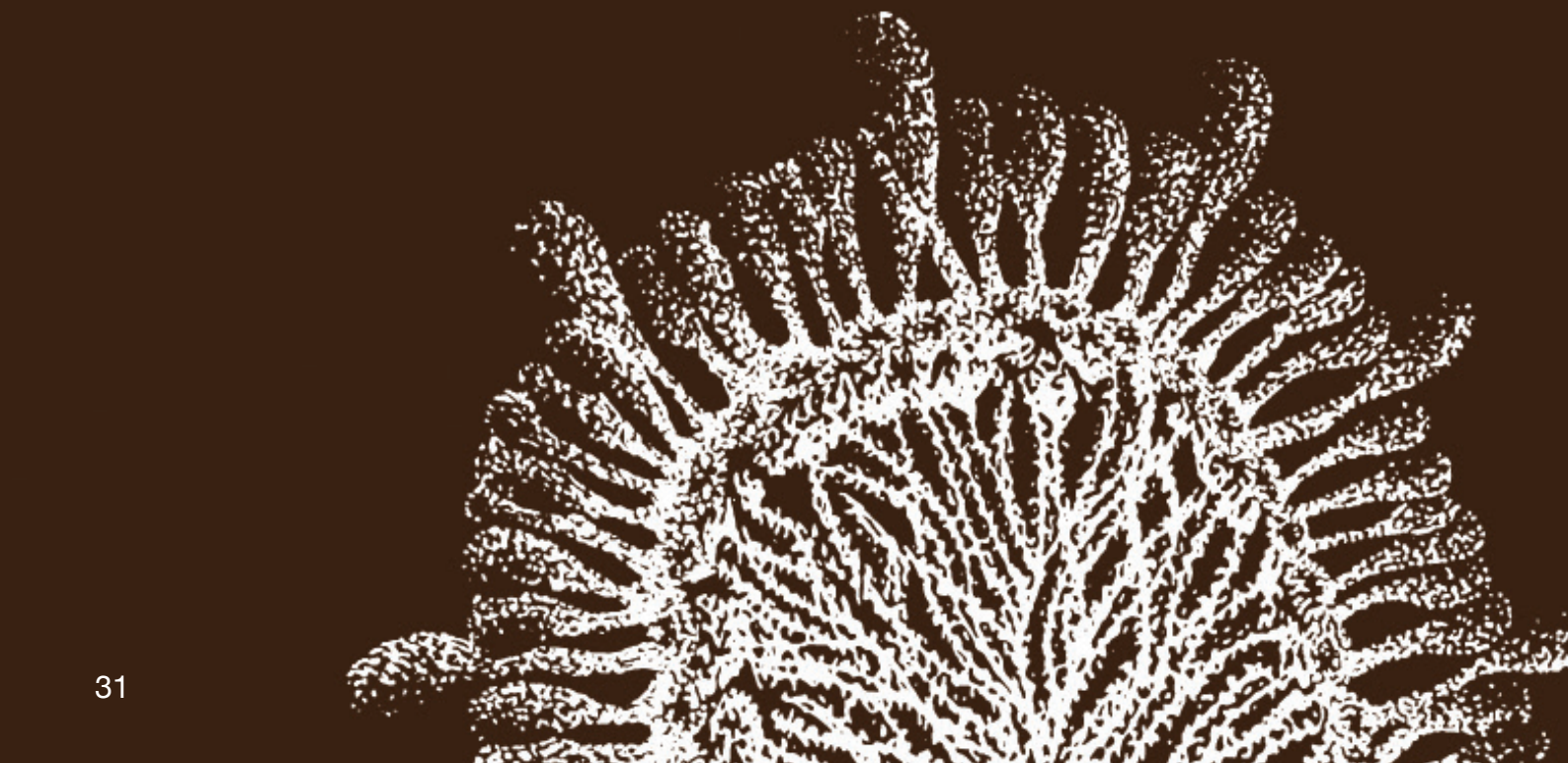
Fig. 7. Photo by author, overgrown bag of oyster mycelium grainspawn, 2023.

"...imagination can make situations appear very dramatic, but in reality, the situations of the lacewings or mice is far more dramatic than the imagination of the author. Many of the lacewings died, one mouse drowned as she fell into a watering can, their reality is thus about living and dying whereas the author's reality is very much about comfort and discomfort, which is also very subjective and relative. However, the events make visible some of the already existing forms of multispecies cohabitation and open up for questions of negotiating space and resources,"

(Svenja Keune 16).



03
Mycelium Materials and the Lab Ecosystem



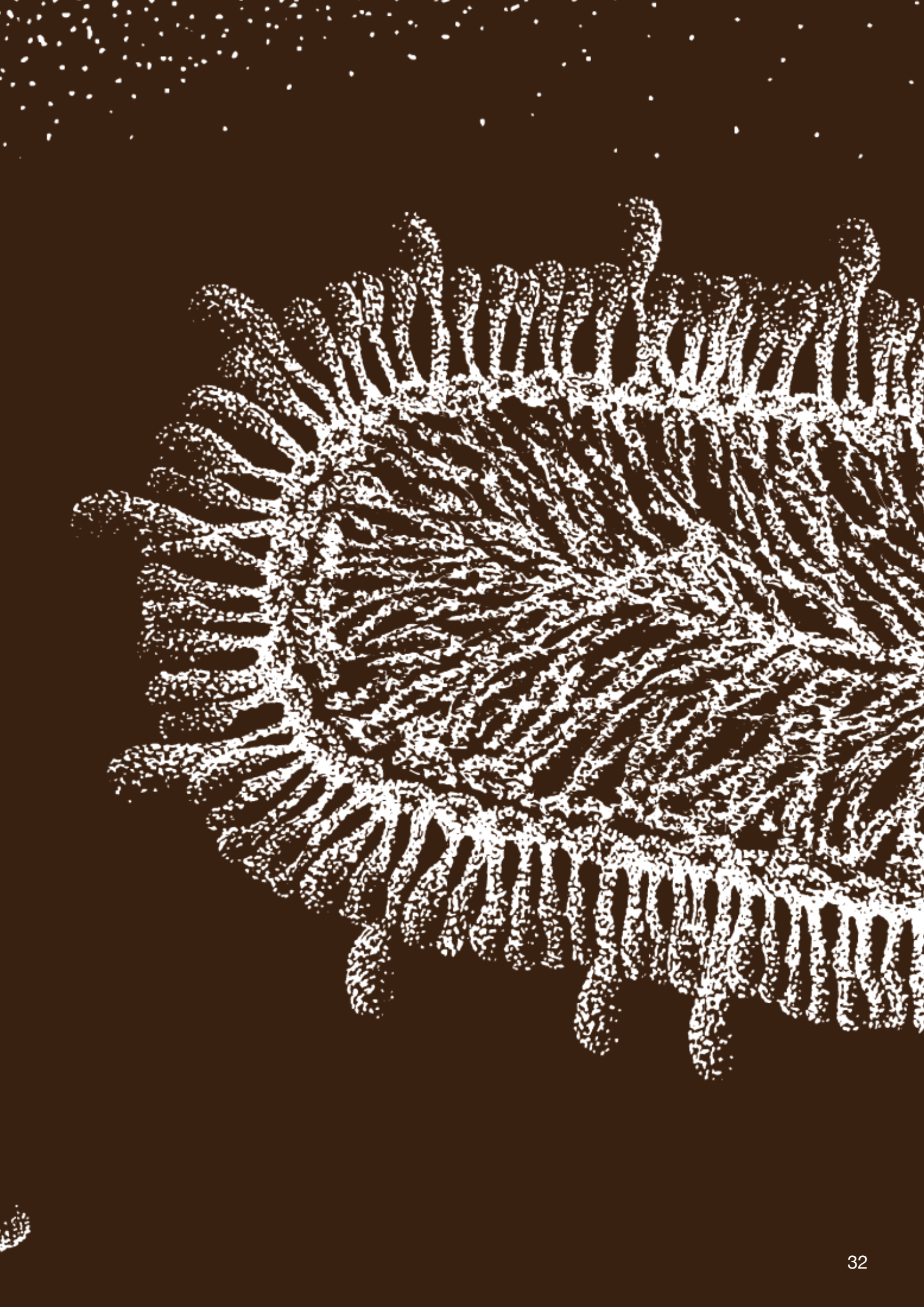


Fig. 8. Photo by Jay van Dijk of material sample by Josef Belton, Oyster mycelium hypae running from peastraw across woodblock, 2023.

Mycelium material process

Mycelium materials are already commercially available as packaging products, designer leather replacements, soundproofing, even surf boards. Mycelium 'leathers' have been known to be produced by people for a long time around the world (Blanchette et al.). The rise of eco-aesthetics has encouraged this material process to become commercially produced. Mycelium leather watches, hats, shoes, and handbags are currently being produced commercially. In the US, Ecovative Design LLC have been key players in scaling up mycelium material production. The company was founded in 2007 by Eben Bayer and Gavin McIntyre who developed their mycelium material process during their Inventor's Studio course at Rensselaer Polytechnic Institute. The pair received funding to develop mycelium materials for protective packaging, structural biocomposites, thermal insulation, and provide 'Grow-it-yourself' kits for people to easily make mycelium materials at home (Zocher and Zeller 51-53). Receiving further awards for innovation and investments to continue scaling up has allowed the company to supply protective packaging to Dell, PUMA, and IKEA. Ecovative also licences their technology to start-ups around the world, like BioFab mentioned earlier. The process I have developed is inspired by the basic steps Ecovative uses to produce their products ("Our Process"). My process differs greatly, however, as Ecovative have developed technology to perfect their mycelium material processes over 16 years.

I designed the Mycelium Material Process diagram (Fig. 9) to visualise pathways that could be explored in this project, and where there are opportunities for co-design. Time is a key ingredient in the mycelium material process. This diagram helps us to see the big picture and in what contexts we should interact with the material. It's also useful for replicating the process, and visually sharing it with others.

The mycelium material process begins with initial design intentions. Here we need to research and make choices about the substrate, mycelium species, and growth conditions we wish to work with. Once we have a plan, a clean work environment, soaked and sterilised substrate, and have acquired all the 'ingredients', we can inoculate the substrate with mycelium. Then we let the mycelium inhabit the substrate, without interacting with it for a few days to a few weeks - this is very dependent on the growing conditions. After this time we have another opportunity for design, to move the inhabited substrate into a mould. If the material is already in its desired form you may not need to do anything here, simply check on your growing conditions and wait until the substrate is almost completely inhabited by mycelium. In our lab we sterilise our substrates in jars and inoculate these directly as they create a sterile environment, which is where this two step growth period comes from. Depending on your intended design outcomes, you may also choose to change the growing conditions of your material. This may be changes to light, temperature or humidity. Once our mycelium has completely inhabited the substrate we have more design choices to make. We can remove the mycelium from the growth vessel and give it more time to grow with oxygen reaching the outside. This can form a 'skin' of fluffy mycelium on the exterior of the material. We can also put it in conditions where the material might fruit mushrooms, or dehydrate the material, killing the mycelium. After this we may choose to further process the material depending on its intended purpose. Once we are happy with the exterior of the material we can dehydrate and further process it. The design intention may however be a living material, in which case we may not dehydrate, but add to the design process in some way, or consider the design process finished.

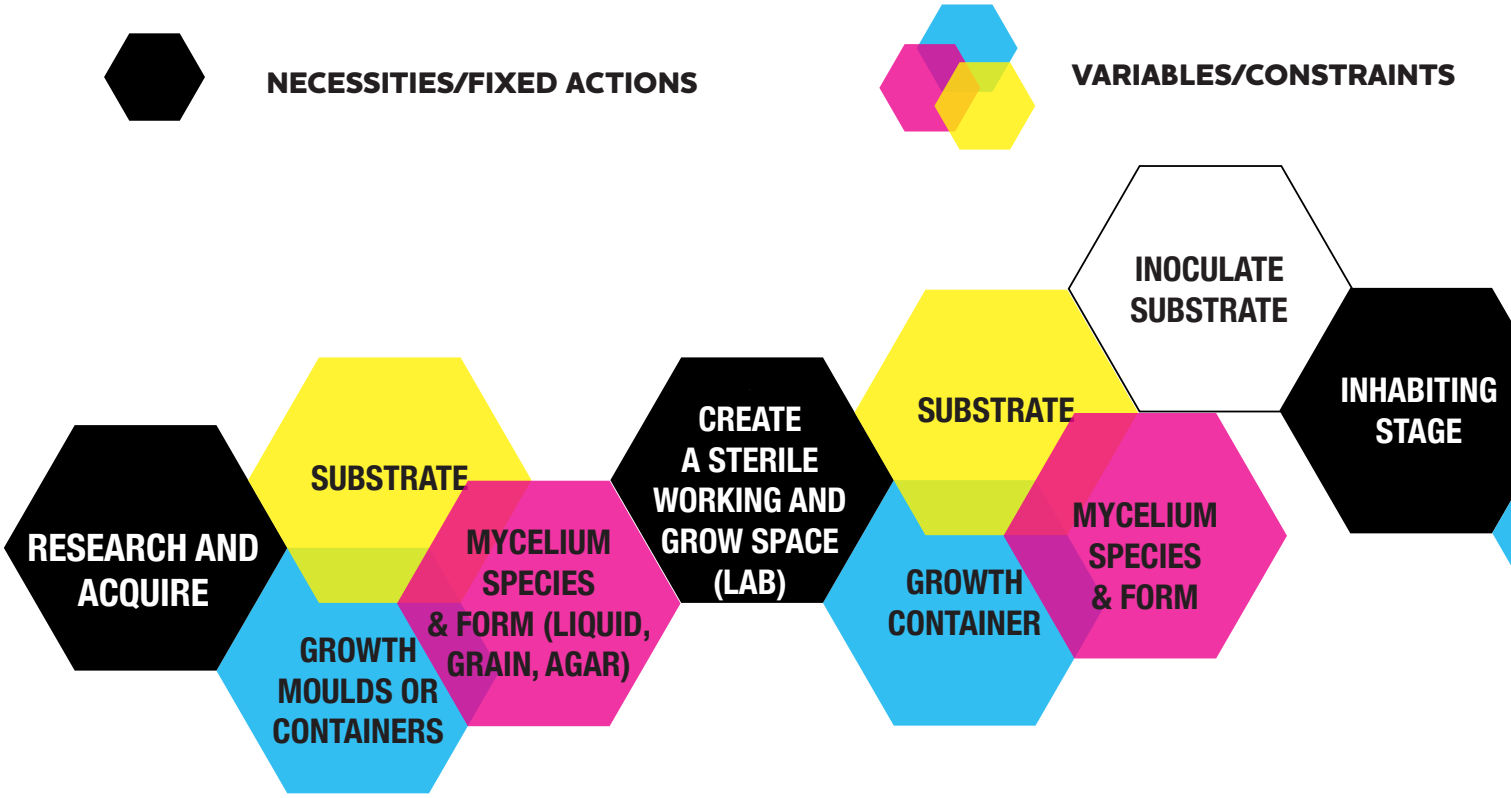
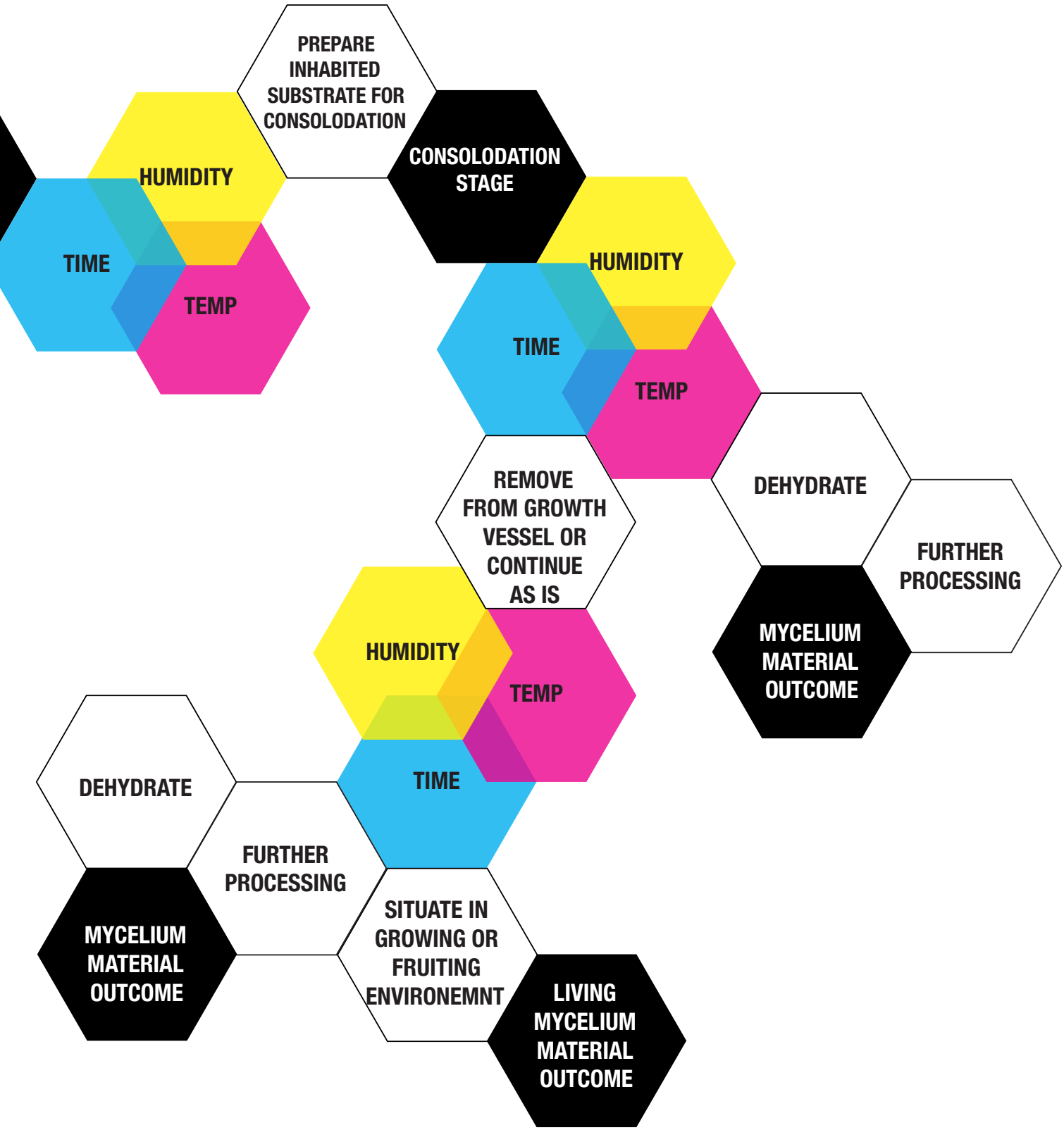


Fig. 9. Diagram by author, Mycelium Material Process, 2021-2023.

OPPORTUNITY FOR DESIGN



Fungi as materials

In this project my closest fungi friends have become the Aotearoa native oyster, Pleorotus pulmonarius (Fig. 11), and the turkey tail, Trametes versicolor (Fig. 10). The particular species I worked with were sourced from MycoLogic, a mushroom passionate company founded by Barton Acres, based in Dunedin. These two fungi grow quite different looking mycelium, but are both valued as materials due to their saprophytic nature and polymeric structure of their cells. ‘Polymers’ are materials made of large repeating molecules (“Polymer”). We often associate polymers with materials such as polyester, or polystyrene, human-made materials. Mycelium are naturally occurring polymers, which is why they have such an exciting material potential as replacements for their chemically derived alternatives (Haneef et al. 2). Figure 12 illustrates the fibrous, network-like growth of mycelium (left), the single celled hyphae (middle), and the large molecule makeup of the hyphae cell wall (right).

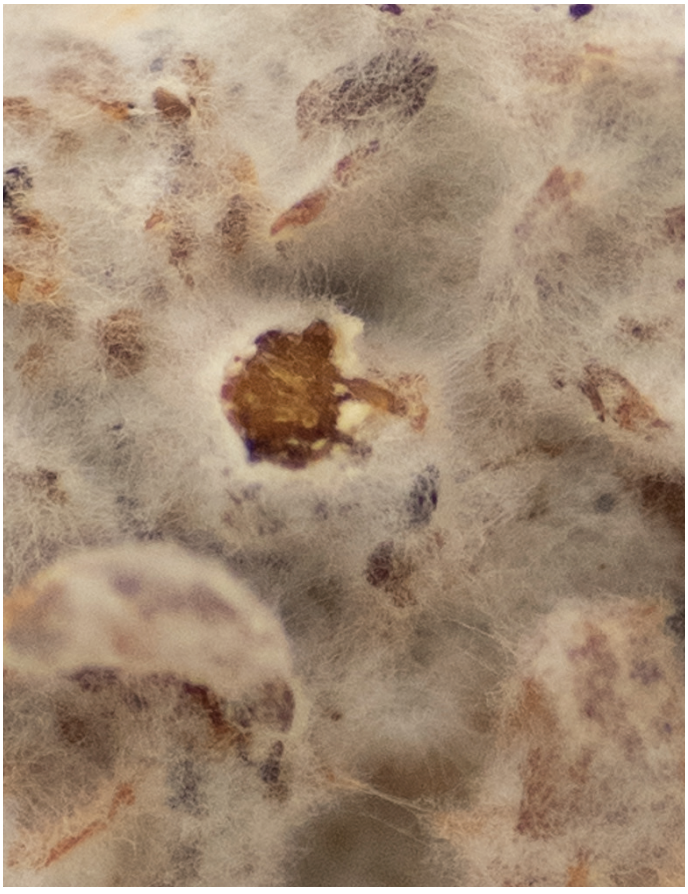


Fig. 10. Photo by author, Turkey Tail (Trametes versicolor) mycelium, 2023

Fig. 11. Photo by Jay van Dijk, sample by Josef Belton, Native Pheonix Oyster (Pleurotus pulmonarius) mycelium, 2023.

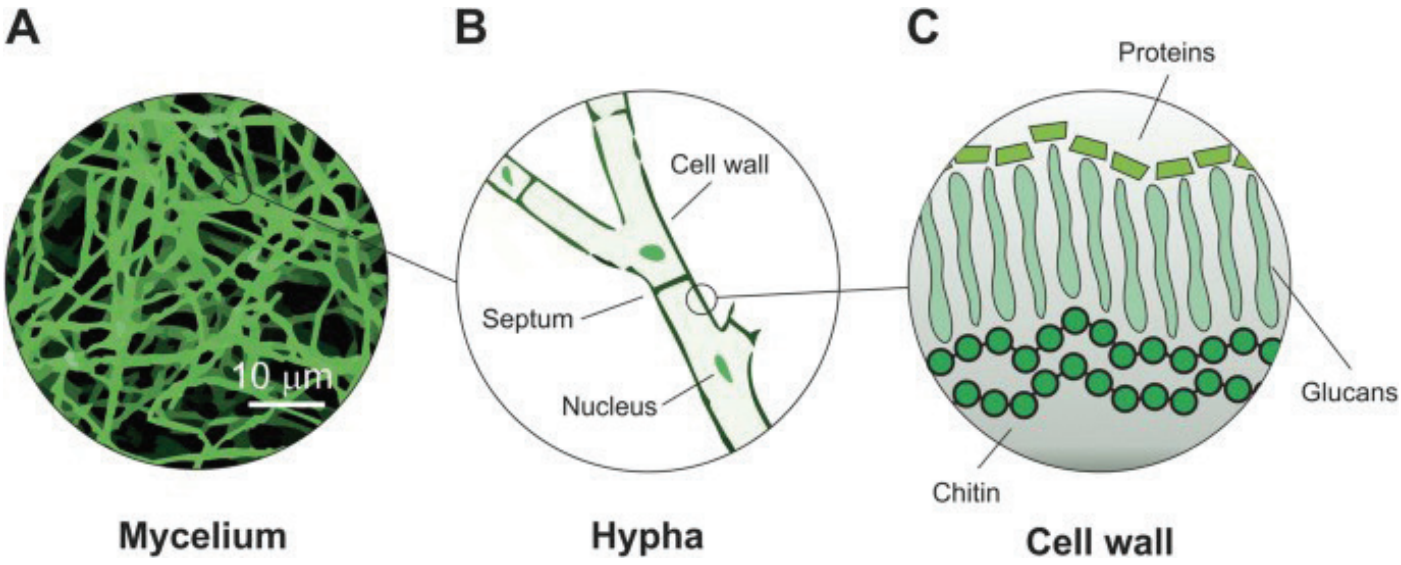


Fig. 12. Haneef et al., Schematic representation of mycelium physiology at different scales, 2017.

Working with mycelium is unlike any material process I have engaged in before, but it still requires a multi-sensory understanding, similar to traditional processes such as weaving. While processes like weaving are very touch-sensitive, mycelium materials are sight-sensitive. This is because we want to have the least physical interaction with the mycelium as possible, as our bodies spread competing spores and bacteria, so we must be able to look and see the signs of growth and change in the material. The idea of 'mycelium running', a term coined by Stamets, is a good descriptor of the way mycelium moves across substrates (125). Mycelium 'runs' in search of nutrition in a substrate or to 'jump' from one substrate to another. In figure 8 we can see long extensions of hyphae running across a piece of wood, extending from its original pea straw substrate. When inoculating a substrate with mycelium we must have an awareness of how active the mycelium is, where the points of contact are between the mycelium hyphae and substrate, and be aware of our interactions causing damage to the mycelium. We must work on mycelium's time to co-create materials. Timing was a particular challenge for me. I made many materials where I had waited too long to put an inoculated substrate into moulds. The mycelium is too far through its life cycle when it is beginning to reach primordia formation, also known as pinning (Fig. 7). From this point it may not be interested in consolidating the material (continuing to run) as it is already forming fruiting bodies. Ideally, materials are moulded when the mycelium has almost entirely inhabited a substrate, about 80-90%. When moulded at this point the mycelium will consolidate in the mould and leave us enough time to demould and dehydrate the material before it starts to pin. However pinning and fruiting may be part of the intended design outcome. The fungi are only one ingredient in the mycelium material. The substrate that the fungi grow throughout, also become part of the material.

Substrates

As mentioned earlier, saprophytic fungi happily grow on many byproducts of human industry. Agricultural crop waste, coffee grounds, and more. There has even been a case of a fungus consuming cigarette butts (Stamets). From our earlier discussions we understand that it is important to face our waste and understand where it goes. Many of these substrates could simply be composted. However our industrial scale activities and lack of composting infrastructure across Aotearoa make this an uncommon occurrence. Mycelium materials can redirect this waste and give it new life for a while longer, hopefully also directing it into home and community composts. The substrates my fungal friends and I have worked with are various kinds of sawdust and wood chips, coffee grinds, logs, pea straw, hemp flour and hemp husk. Hemp husk is a byproduct of the hemp foods industry. The husk is the outer casing of a hemp seed. This is removed from the seed, which is then graded for use, often for the purpose of extracting the two nutrient dense hemp hearts from within. I sourced hemp husk to experiment with as a substrate from Hemp Connect. Sourcing local industry byproducts to create with is a good start to making local symbiotic relationships.

When it comes to designing with natural resources, there can be laws and regulations which dictate the way we use and interact with them. Some make positive impacts on ecosystems, others do not. While businesses like Hemp Connect make use of hemp seeds, many parts of the hemp plant are known to be great, nutritious substrates for mycelium. Unfortunately, the cultivation and commercial use of hemp is regulated under the Misuse of Drugs (Industrial Hemp) Regulations 2006 and the Misuse of Drugs Act 1975 (Misuse of Drugs). Under this regime entities and individuals are required to obtain a licence from the Ministry of Health to cultivate, process and sell hemp products. The Ministry of Health's guidelines require that hemp waste must be disposed of in ways which ensure it will not be obtained by those without a licence and enter the illicit drug market. These guidelines make it difficult for hemp biomass to be industrially composted as the composting entity would also be required to hold a hemp licence. This means a large portion of rich hemp biomass is being sent to landfills. It also poses challenges to redirecting the waste towards uses like mycelium materials.

Fig. 13. Photo by author, dried hemp plant, 2023.
Fig. 14. Photo by author, hemp husks, 2023.

The lab ecosystem

The kind of environment you design for a mycelium material will depend on the species you work with, the substrate you feed it, and what choices you make when interacting with the material. Different species have differing preferences for temperature and humidity, and varying levels of resilience to other organisms like bacterias and moulds. There is a lot of variability when designing mycelium materials. Commercially, mycelium materials are made within a fungi-optimal environment; not too hot, not too cold, just the right amount of humidity, and zero competition. The specifics of these are dependent on which species of fungi you are working with. Turkey Tail (trametes versicolor) generally prefers temperatures of 10-28ºC and 60-85% humidity and the Native Phoenix Oyster fungi prefer 15-20ºC environments and 75-85% humidity (Acres). Our mycelium lab was not set up with perfect temperature and humidity controls, however we still had successful results (Fig. 27) among some unsuccessful results (Fig. 28).

I chose to build a small, affordable, lab in the Textile department at Massey University, on the Pukeahu campus, Te Whanganui-a-Tara. This is a vibrant ecosystem of students and researchers engaging in so many different textile processes. Our Lab ecosystem is located at the end of an L shaped room which houses tools, machines, and space for exploring synthetic and natural dyeing processes. To give our mycelium friends the best environment for contaminant-free growth we constructed two ‘tents’, one which acts as a still air box for doing sterile work, the other for the mycelium to grow in little light and low contamination (Fig. 15). This design has just enough space for one person to do sterile work, but does not have a filtration system. The space gets quite warm and dense with isopropyl alcohol scents in the air if we are doing lots of work at once. I share this space with other textile students and researchers, most often with natural dye researchers, so the environment is not totally dedicated to mycelium growth and there is plant matter and other substances often brought into the space. Despite this our ecosystem has been able to support the co-creation of mycelium biocomposites, and as the ecosystem develops our processes begin to include ‘contaminants’.

Fin Georgeson and Josef Belton are two other design students who joined the Lab ecosystem in 2023 to explore mycelium materials in the contexts of their own design disciplines, Industrial, and Spatial. Both students came to me individually as they wanted to incorporate mycelium materials into their design practices. Due to the lengthy nature of the process and our simple lab set up, we decided to collaborate on some material samples to expand our material understandings of mycelium. Everyone contributed various substrates they were interested in, all of which are locally sourced byproducts or waste products. We took turns at completing different stages of the process from pressure sterilising substrate, to inoculating sterile substrates, moulding inhabited substrates, demoulding, and dehydrating. Figure 16 shows a couple of coffee grinds and mycelium samples by Fin and I.

Fig. 15. Photo by Josef Belton, Author in Mycelium Material Lab, 2023.

Relationships are like a 2D double helix. Coming together, being apart, and coming together again. One of the most insightful relationships I've experienced brought this knowledge to my attention, through my friend Hannah. Our own relationship has reflected this idea. We have loved each other, we lived together, we worked together, we fought a lot, we hated each other, we missed each other, and we love each other again. We continue to weave our lives separately, but always intersecting. When we do intersect, we talk about how we've grown and changed, sharing newfound introspective knowledge with each other. We discuss the metaphysical world as we see it meet with the material one. Like the idea that we experience relationships as double helix. They're like DNA. We provide each other with meaning that twists and turns right through to the centre of each cell making up our body. Like yarn being spun, wavy sheep's wool fibres locking into place - there's micro spaces in there. Space has to be present for there to be intersection, even if it's the tiniest nano millimetre. Like the double helix experience of relationships. We make space and grow, we intersect and grow.

Fig. 16. Photo by author, material samples by author and Fin Georgeson, 2023.

Fig. 17-18. Photos by author, Josef Belton and author in the Mycelium Material Lab, 2023.

Lab diary

In textiles and materials design we need to record what we do in order to share valuable information with others and recreate our outcomes. Through-out this project, myself and other students collaborating in the mycelium lab, have kept a detailed diary to share our experiences and refer back to. Here we have recorded the timeline, moon phases, actions, observations, sometimes images, and reflections. This is a real-time recording of lab activities which demonstrates the extensive relationship building that was undertaken with mycelium. Figure 19 is an example section of the diary. The full diary can be viewed in the accompanying digital workbook at:

https://gen-rae.notion.site/Lab-Diary-cebf7b59ea8540e6a025081be708ced5?pvs=4.

masters / Lab Diary

Aa Date & Moon	Actions
29-05-23 63% waxing	The open samples are beginning to fruit quite a bit and have developed a little bit of a skin on them. Got the dehydrator moved out of the room.
31-05-23 81% Waxing	Submerged the log to soak up moisture
01-06-23 88% waxing	Put inhabited pea straw leftover from Josef's project around the base of the log in a metal bowl.
14-06-23 18% waning	Gen and Fin in the lab Sterilising hemp flour, hemp husk and coffee chaff. Buried material in Earthworms garden
16-06-23 5% wa OPEN	Gen and Fin in Lab Inoculated sterilised stuff from 14-06-23 w TT 50:50 chaff:grain in jar. 3/4 grain with bucket chaff. 3/4 hemp husk 1/4 grain in jar. & Hemp flour Collecting 4 different sections of dirt for Lab dirt experiments. 1. rich and dark under thick leaf litter - war memorial 2. rich and dark but more dense and clay like under moss - war memorial 3. Dry and dusty from tree planter box - gets lots of sun thin leaf litter - war memorial
19-06-23 1% Waxing	Fin set up the BReactor Gen made 4 PDA plates 3 x square 1x round Fin inoculated plates with TT spawn from the chaff bucket so we didn't have to open up a fresh bag. Round petri dish with TT spawn is going in the

Calculate

Fig. 19. Image by author, screenshot of the lab diary, 2023.

Edited 2d ago G F

Observations & Reflections	Images
We really need to move the dehydrator out of the room because it's sucking the humidity. Josef's model which was in the working tent is looking dryish on the outside.	
Chaff is clumpy and wet. Hemp Flour and hemp husk are very dry. Hemp husk is wet at base. Interested to see if the mycelium minds the damp clumps in the chaff.	
Checked on inoculated substrates, all starting to show mycelial growth. Added water and iso to the hemp flour jar. Mycelium log looking good, added water to the bowl.	

Sterile Practise

In a lab environment, sterile practice is important to the production of mycelium materials to avoid contamination and create uniform materials. We breathe hundreds to thousands of fungal spores everyday (Stamets). Spores can also cling to our clothing and bacterias live on our skin. These are symbiotic relationships that are unavoidable, so we must be careful when interacting with fungi for material purposes. In the lab we synthesise the perfect environment for our intended fungi co-workers to grow in, but it is also the perfect environment for the unintentional spores, bacteria and moulds that we carry in with us. Aside from a substrate sterilisation process (for us this is the pressure cooker), and a clean work space, essential tools for achieving sterile practice are PPE (personal protective equipment), 70% isopropyl alcohol, access to hot soapy water, paper towels, and other cleaning equipment like a vacuum cleaner can be useful. 70% isopropyl alcohol with 30% water is the optimal ratio for sterilising surfaces. The water allows the alcohol more contact time with the surface before it evaporates, ensuring the surface is clean.

In our lab environment we do not have a laminar flow hood, nor did we use facemasks, outside of periods where social distancing was necessary. We would try our best not to speak or breathe heavily over samples and substrates, sometimes pulling our shirts over our nose and mouth. In future I would ensure the use of facemasks in the still-air tent and when inspecting samples in the grow tent. We wore plastic gloves which would also be sterilised with 70% isopropyl alcohol, but not lab coats. I would also in future recommend the use of lab coats if they were able to be cleaned or steam sterilised after each use.

Many of the tools and materials used in lab mycology have negative impacts on wild ecosystems after their use. Paper towels can be composted, however it might be more sustainable to use natural fibre compostable cloths which can be sterilised on a regular basis. Plastic gloves are a difficult one to get around in terms of sustainability. There are very few bioplastics in existence which compost efficiently. The necessity of a sterile environment makes lab ecosystems difficult to align with sustainable practices as commonly available tools are often plastic and single-use.

Preparation

- Put on your PPE: Wear gloves, a face mask, and a lab coat to minimise contamination from your body.
- Clean your workspace: Wipe down the work area with isopropyl alcohol to remove any potential contaminants.
- Sterilise tools inside the already sterile work area: Sterilise any tools or containers with isopropyl alcohol.
- Before opening mycelium culture containers, wipe the outsides with isopropyl alcohol and a paper towel to minimise external contamination.

Inoculation

- Sanitise your gloved hands: Apply isopropyl alcohol to your gloves, rubbing them together to ensure coverage.
- Open the mycelium culture: Carefully open the mycelium culture container without touching the inside of the lid or the container itself.
- Transfer mycelium: Use sterilised tools (e.g., forceps, scalpel, or gloved hand) to transfer the mycelium. Avoid touching any non-sterile surfaces or breathing/talking directly onto the mycelium.
- Seal the container: Close the sterile container immediately after transferring the mycelium to prevent contamination.

Grow Space Maintenance

- Cleaning the grow space: Regularly clean the grow space by wiping down surfaces with isopropyl alcohol. We clean the still air tent after each use, taking care with removing any substrate matter that may support contaminants. If multiple samples become contaminated inside the grow tent a deep clean is required with hot soapy water and isopropyl alcohol.

Cleanup

- Reusable containers and tools: Wash any used containers and tools with hot soapy water. Rinse, dry and store them in a clean and dry area for future use.
- Composting waste: Most mycelium material waste or unused substrate can be composted. We composted our compostable waste in the Earthworms Club compost bins located on campus.
- Clean PPE: Reusable PPE should be washed and dried after each use.

Non-sterile practices

While materials produced for commercial applications need to be free from contamination, there is space for mycelium materials to become contaminated or invite in other life. In natural ecosystems most fungi rely on other organisms and certain conditions to survive. They also provide value to the ecosystems they exist in. Early in my project I disposed of some mycelium samples by putting them underneath logs near my tapestry frame. After a few months mushrooms were fruiting out of them. We got two very decent flushes of oyster mushrooms which gifted my flat of six people a delicious meal. Several months after this I almost tripped on one of these logs and it crumbled away. I noticed inside they were essentially rich soil, or hummus in the shape of a log. This soil is so valuable for plant growth. I moved some of the logs and crumbled them over my vege patch. The oyster fungi helped feed my family with their fruits and made their contribution to the soil we grow food in.

Experimental design and material research studio Aléa are breaking mycelium out of the industrialised lab environment to co-design materials and objects in the soil. Their method is a reciprocal approach to making where the mycelium is no longer isolated from its natural ecosystem. In this manufacturing process the co-designers also co-benefit.

> "This exploration challenges the role of the designer and control over material and imagines new ways of making that benefit the more-than-human, acknowledging that our needs and that of nature are deeply intertwined," ("The Aléa Method").

Inspired by this, Fin and I attempted our own mycelium - soil collaborations with locally sourced substrates. These explorations took place in the ecosystem of the Earthworms Club māra kai, on the Pukeahu Massey University campus. In our first attempt, we dug a hole and filled it with layers of oyster mycelium grain spawn and chaff, a coffee roasting byproduct. We had not tested this substrate with our co-workers in the lab environment and it was unfortunately unsuccessful. While the mycelium didn't love the chaff, there were signs that the growth environment could be very successful with the right substrates. We also collected three different compositions of dirt from around the campus to simulate the soil environment in the lab. While these also showed promise, we had a large contamination of blue mould which took over our lab ecosystem at this time. Our second attempt in the Earthworms māra was conducted in a different spot to the first one, with shredded paper and coffee grinds as substrates both sourced from the university campus. This new hole was far too wet, winter had set in slowing outdoor mycelium growth, and the substrate did not allow enough oxygen to filter throughout the sample. There is not enough time or resources to reach a successful result with this method within the scope of this project. However Fin and I will continue to test this method as he completes his Industrial Design project, endeavouring to create a portable composting toilet. If we are able to produce mycelium materials in the soil of areas which are depleted in diversity and nutrition, this process would be far more sustainable compared to mycelium material processes performed within a lab ecosystem.

Some symbiotic relationships require humans to intentionally give an ecosystem space to thrive. In the Lab we would discuss the anthropocentric act of removing mycelium from its natural ecosystems for the industrial production of materials and how we could respond to this. Anthropocentric refers to the concept of the anthropocene; an era characterised by human-centred activities as contributors to the Earth's changing climate (Lewis and Maslin; Folke et al.). Josef responded to a Spatial Design brief with a speculative architectural installation entitled Consumption (Fig. 20-21). This project was made of an MDF frame and panels of oyster mushroom inhabited pea straw. The structure is designed to invite non-human inhabitants, micro-life like our fungal friends, to reside in the space making it unfit for humans. The structure will eventually be consumed by decay and its parts will return to the ecosystem, nourishing it in the process. There is significant ecological value in designing environments which are not made for long-term, frequent human interaction.

Fig. 20-21. Photos by author, Josef Belton's 'Consumption', 2023.

Fig. 22. Photo by author, Alea Method sample by author and Fin Georgeson, 2023.

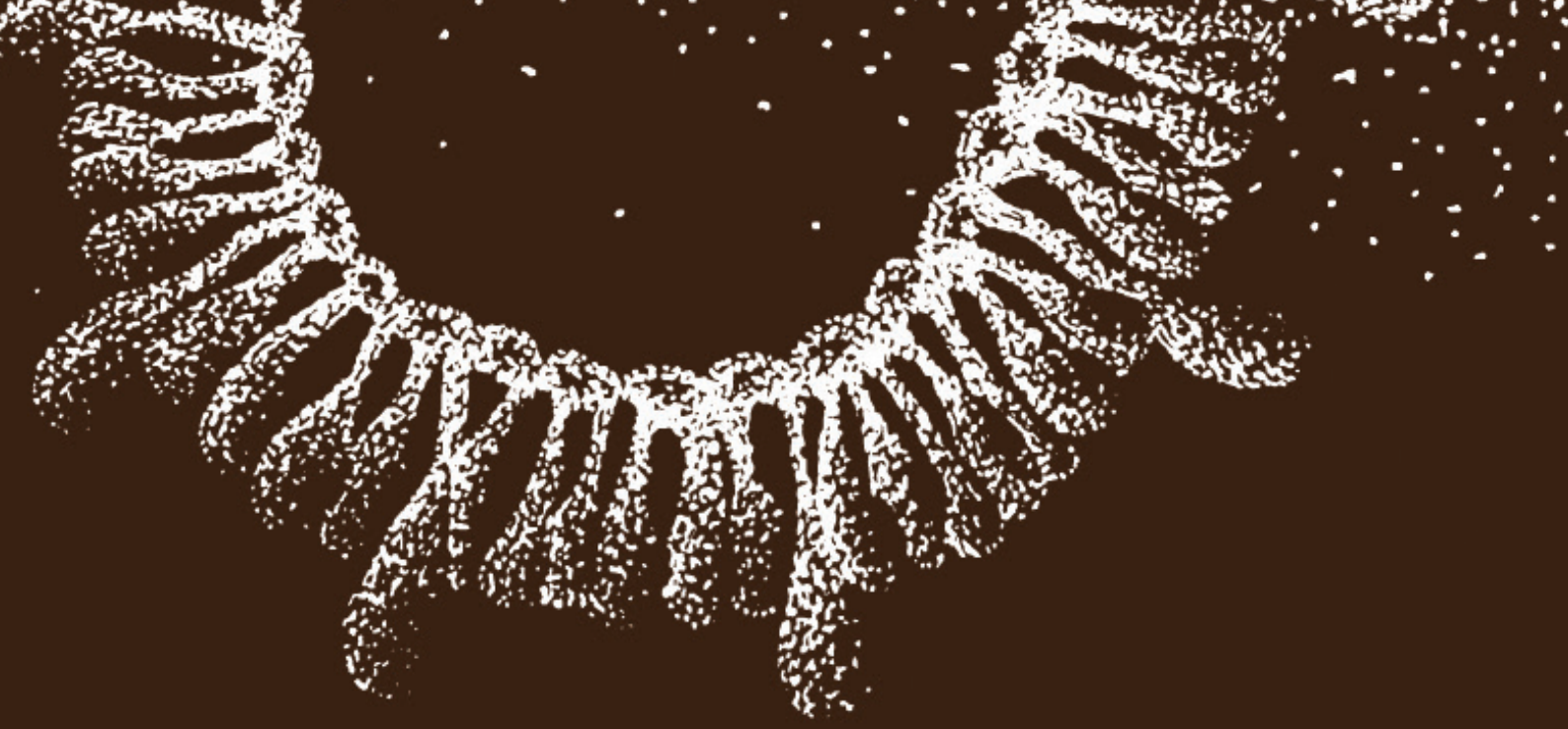
Fig. 23-26. Photos by author, Alea Method explorations by author and Fin Georgeson, 2023.

I'm able to perceive materials with a life force, with something of their own that they're bringing to the table. With energy to be transferred and transformed. Something continuing to exist that I can relate myself to. This perception helps me see how we are constantly weaving relationships with objects and materials, forgetting some things exist and coming back to them months later. I see our relationships with 'waste'; taking, making, using, and discarding - I guess our next lives will meet these discarded materials again via the environmental issues their neglected state will cause.

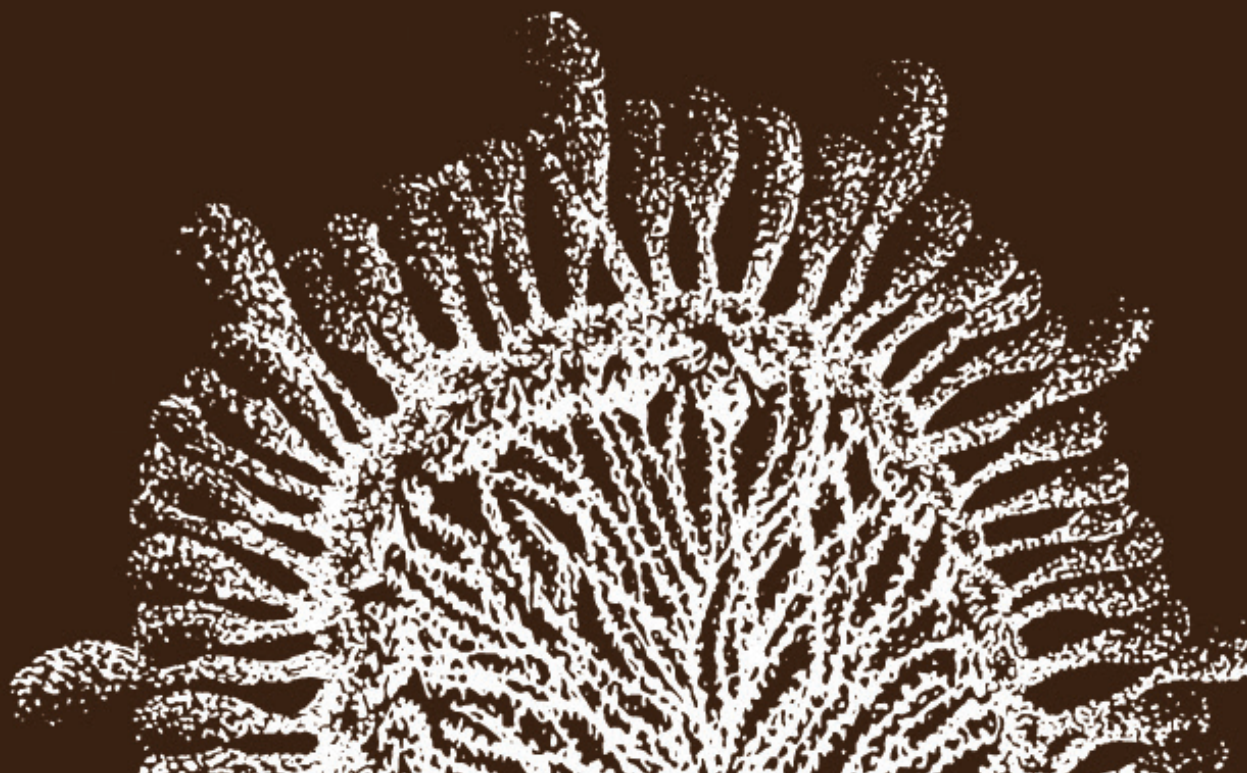
This perception is amplified as I build a relationship with mycelium. I have much less physical interaction with mycelial threads than any other threads I've previously worked with. The organism chooses the best route for itself and I just provide the potential pathways. We intersect and are making something together, but in our own space we are learning, growing, and making decisions. This space feeds back into the design of the material, where we come together. We are co-designers continuing to take the twists of the double helix.

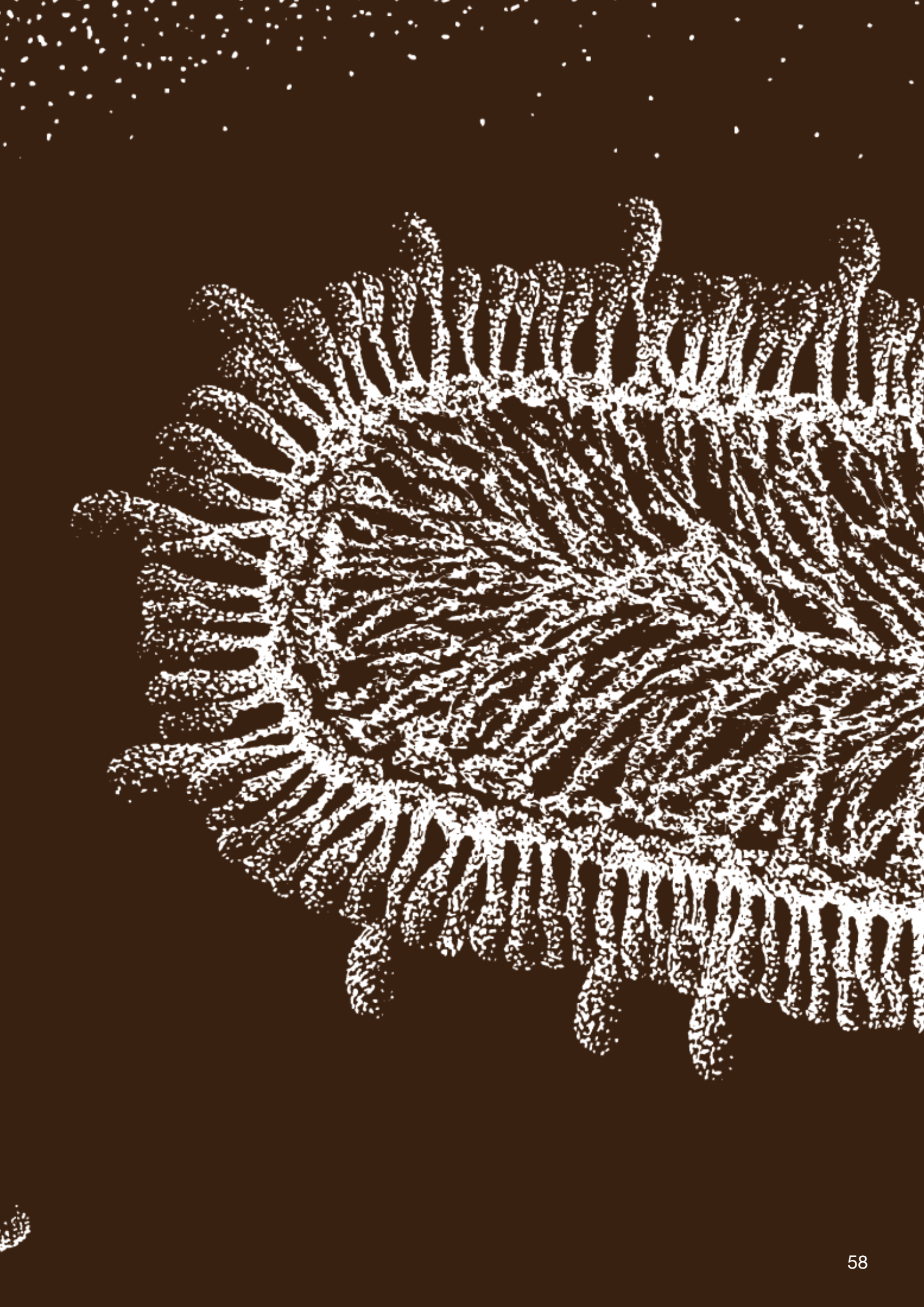
Fig. 27. Photo by author, contaminated mycelium material sample, 2023.

Fig. 28. Photo by author, mycelium material sample, 2023.



04 Weaving Habitats





Contemplating creation and decomposition

To be alive is to experience life, and death is as much a part of life as living is. Death is not only found at the end of life. We have little deaths all the time. We just call it change instead. When we decide to find a new job, end a relationship, or discard an item we no longer need or can make use of, we are in the process of letting things end. Parts of ourselves and the spaces we inhabit die off all the time. This is what I see when I walk along the beach. Take a barefoot step and let the sand sink a little, a release. We let it happen and take another step forward, knowing that the footsteps behind us will be licked away by the ocean, tomorrow becoming changed, something new. The letting go, the little death, is as much a part of life as living is.

My mycelium friends and their wild co-workers remind me of death all the time. In the wild, fungi and other microorganisms live in death. By this I mean they break down what has died, or is dying. From a fungi's perspective, something that has died is not a carcass, nor does it make it time for a funeral. To them it is food, time for a feast, time to return a mass of cells that is no longer serving a purpose back to the ecosystem so they might find new purpose. Fungi turn death back into life. They are makers of the forest floor.

One of the most valuable lessons saprophytic fungi have taught me, is that death is also the start of life. I find myself getting so tied up in stories sometimes, believing there is a beginning, a middle, and an end. But in reality, there is only a verb-like unfolding - change, or transformation.

Fungi are happy death keepers, they whisper prayers in the ears of dead trees as they consume and decay the tree's physical body. Mycelium works its hyphae throughout the wood. This creates channels for water, oxygen, and nutrients to travel in and support other microbial life who continue to break things down.

There are other natural entities taking on a similar role, but in soil. I recently learnt that certain types of weeds can indicate the state of the soil in a particular area. Humans and weeds have a long standing relationship. We love to cause destruction, and weeds love to grow where destruction has been done. They also love to be destroyed in ways that will spread their seeds and allow them to reproduce.

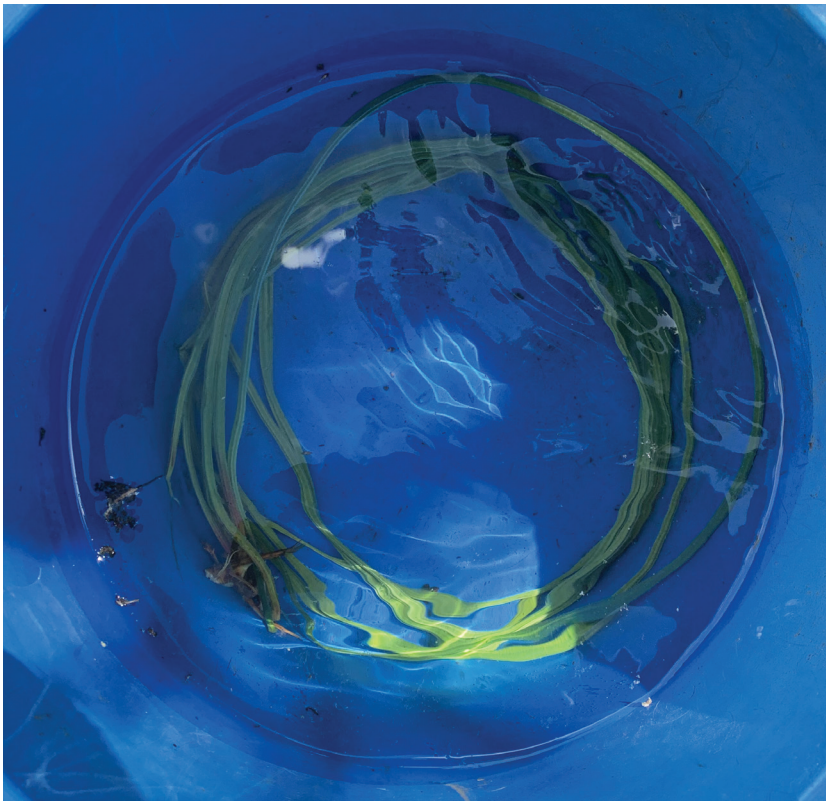
In my time weaving I have been building a relationship with narrow-leaf plantain, Plantago lanceolata, a weed that grows all over Aotearoa. Plantain is often separated into narrow-leaf, which is growing in my garden, and broad-leaf. It is often eaten by livestock and is sometimes intentionally sewn for feed. When growing voluntarily, plantain can indicate that the surrounding soil is heavy in clay, not very fertile, and compact. Young leaves can be eaten or made into a tea that has historically been used as cough medicine.

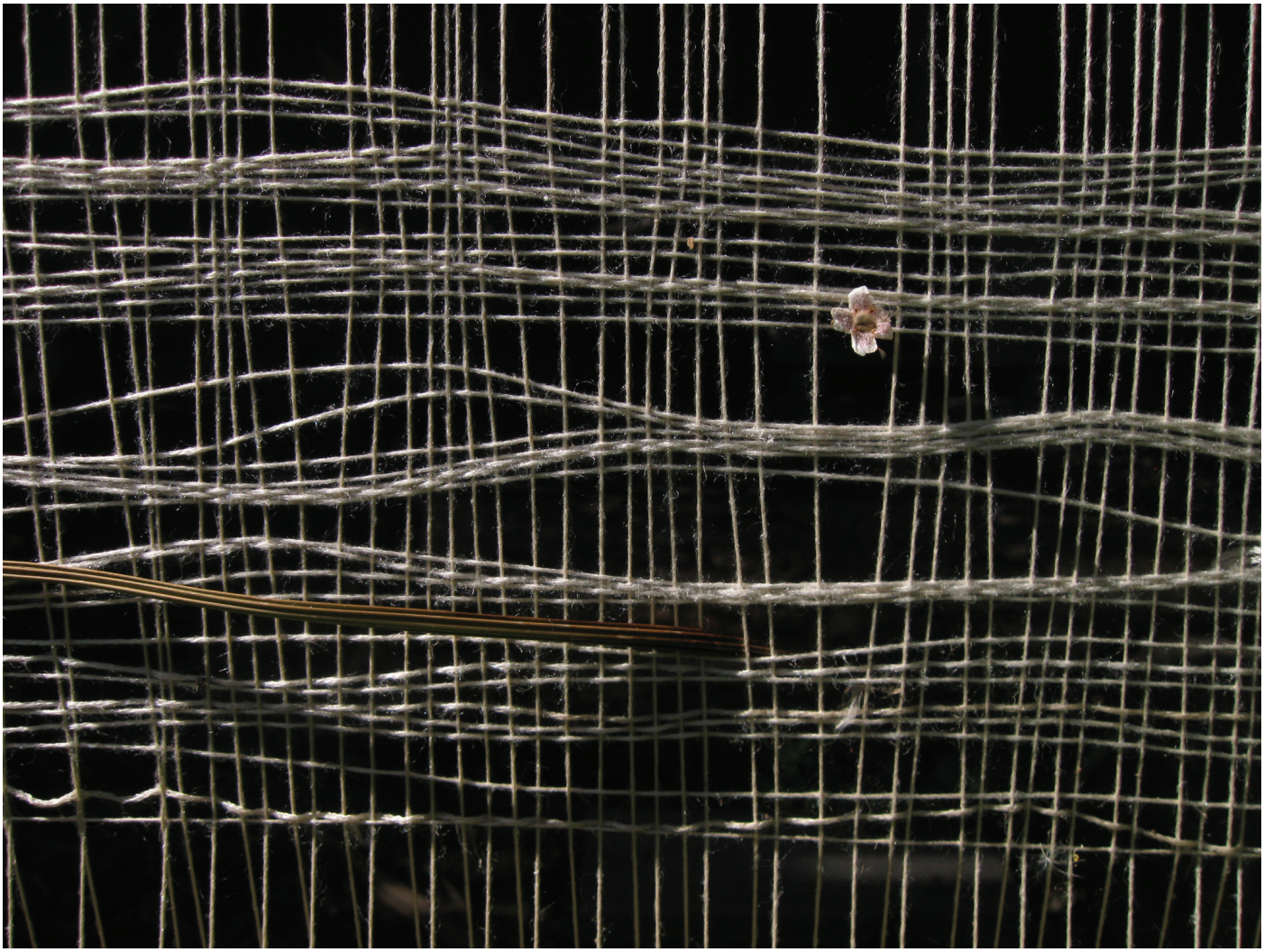
To me, this weed looks like a plant that could be woven. Its long, fibrous stems stretch in and out of my warp. One day I picked some to try retting them. This is the process of soaking natural resources (often leaves or stems) in water for over 24 hours, sometimes over 72, until cellulose in the resource has broken down and separated from the fibres within. They have been soaking for over a week now and are still green and strong, no cellulose breakdown that I can see. I might have to dry and rehydrate these instead. This won't make them suitable for fine textiles weaving but perhaps for basket weaving. I wove a fresh stalk into my weft so I can note its changes over time.

Fig. 29. Photo by author, Plantain weed flowers and tapestry, 2022.

This is the first time I thought to include the plants around me in what I was making. In a later weaving session I noticed little Tī Kōuka blossoms lying on the ground. They're a perfect cartoon flower shape in their entirety, no separate petals. My interactions with the plantain inspired me to sew some of these little gems onto the piece. I don't expect them to last forever - at some point they're likely to be ripped off by the wind, or shrivel and crack. The atoms they are made of will return to the earth.

Just as I and my weaving will. An uncomfortable, but grounding thought. As I practise multispecies philosophy it seems like this is the point I continue to come back to. It's as though the non-human entities in my environment are continually trying to remind me of the reality that death is as much a part of life as living is. Each being in this world plays their part in life and death. Each species acts as death keeper for another.





(opposite) Fig. 30. Photo by author, Plantain in bucket of water, 2022.

Fig. 31. Photo by author, tapestry detail, 2022.

Well being and being-with the outdoors

Spending time in natural green spaces improves my sense of well being and nature connectedness. In a study by Schebella et al. on the wellbeing benefits associated with perceived and measured biodiversity in Australian urban green spaces, they found that "psychological benefits were associated most strongly with vegetation cover," (17). Wohlleben in *The Hidden Life of Trees* presents many reasons for why we might feel so at ease under a naturally occuring forest canopy. The air is a lot cleaner than human dominant spaces because large groups of trees act as air filters. Their leaves or needles catch pollutants, soot, pollen, dust and more harmful particles from human activity such as acids, toxic hydrocarbons and nitrogen compounds. Additionally, trees produce scent messages to communicate with each other, and chemicals or essential oils to protect themselves from parasites and diseases. These smells affect our bodies and experience as we breathe them in. Wolleben speculates that forests planted in areas that the tree species doesn't naturally grow in, may have more stress scent signals swirling around the canopy and perhaps we could pick this up. In theory naturally occurring environments would be releasing more contented communications, having calming effects on our bodies (Wolleben, 221-226). A study based in Korea found that elderly women walking through forests experience improved blood pressure, lung capacity, and elasticity in their arteries, while no changes were found in those who walk through urban areas. Lee and Lee hypothesise that forest environments have antioxidant and antiinflammatory properties found in the scents they release, called phytoncides (9-10).

Biodiversity is important to human health (Mills et al.). We share our indoor spaces with other species like pets, flies, spiders and moulds, probably dust mites and other microorganisms. However, outdoors there is significantly more biodiversity. Especially in the garden at my flat, which we've let get quite wild. I started weaving the 'weeds' into my tapestry, most of them from within a metre of the frame. I think bringing this plant habitat into the piece is what invited so many insect interactions. The bugs joined the tapestry to continue to be part of the plant's ecosystem. If we are practising multispecies philosophy we need to be interacting with a range of species. To design for natural systems, we need to spend time being-with them in order to understand how we can co-design with them (Keune 7-9). We need to be perceiving these interactions as relationship building. The tapestry grew and developed with the habitat and inhabitants of this space. It truly has a 'life force'. It's a living work co-created with plants, spiders, insects, mosses, and so much more. The tapestry has been a conduit of relationship building between this small ecosystem and myself.

Fig. 32. Photo by author, skein of silk, 2022.

Well being and craft

Craft is also a process of relationship building, with materials, my environment, and myself. Engaging in a craft practice has been shown to reduce stress, producing changes in sensory experience, patterns of thought, actions and behaviour (Pöllänen; Huotilainen et al.; Bak-Andersen 32-43). Personally, working with materials grounds me in what is, brings peace of mind, emotional regulation, and a state of flow. Setting aside time to get into the body and be-with the physical reality gives our bodies space to move from the sympathetic nervous system to the parasympathetic. From a calm, present state we are better able to respond to our environment, rather than react, and more easily experience a sense of connection. This idea of relational ease through embodied material experience was first articulated to me in a panel
statement by Anni Albers:

> “Most of our lives we live closed up in ourselves, with a longing not to be alone, to include others in that life that is invisible and intangible. To make it visible and tangible, we need light and material, any material. And any material can take on the burden of what had been brewing in our consciousness or sub-consciousness, in our awareness or in our dreams. Now, material, any material obeys laws of its own, laws recognizably given to it by the reigning forces of nature or imposed by us on those materials that are created by our brain, such as sound, words, colors, illusions of space—laws of old or newly invented. We may follow them or oppose them, but they are guidelines, positive or negative,” (Albers).

Craft is not presented here as a means for improving mental health, but to draw attention to the important relationship between the embodied cognitive experience of working with tools, materials, and the mind (Bak-Andersen 35). I have found the further I develop my skills and practice as a crafter, the easier it is to feel calmed and fulfilled through the activity of craft. A craft practice is a relationship between the crafter, the material, the tools, and subsequently the ecosystem.

When I weave I come back to us. We yarn with the threads and let narrative go. Developing and discussing ideas not segmented by time but by patterns. To come back from this place we put patterns in the hierarchy time asks for, because narrative asks for time. We weave and come back to me. Now understanding where we are in the story that cradles us.

Tools with agency

An often overlooked aspect of a design process is the material reality of tools. Tools are functioning materials, with an agency, life force, and environmental impacts of their own. Our engagement with tools in design is, in its own way, a material collaboration. When crafting, there is a dialogue between the maker, tool, and material (Bak-Andersen 35-37). Tinkering, and crafting are two aspects of textiles and materials design which directly involve tools in the process of forming a design. It is important to acknowledge the abilities and limitations of tools as well as those of materials. The tools which assisted me in creating the outdoor loom are; a bandsaw borrowed from a friend, for making dents in the frame; the flat-owned drill, to fix the beams in place; a large carpeting needle inherited from my late grandmother, this did most of the weaving with me; a spray bottle of water to hydrate the warp and prevent breakage; the gumboots that keep my feet safe in the cold, wet months; a sunhat that shades me; etc. I could create a massive list of the materials and tools that contributed to the creation of this piece.

In reflection what drew me more towards textiles was the tools. Each design discipline more or less uses a certain set of tools. Thinking tools, making tools, software, organisation etc. Textile designers have an embodied experience of what they create. We feel the tension, density, and vibrations of what we make through our skin, our nervous systems. We also feel and learn how changes that we make, change the outcome of the textile, and this changes the experience, qualities, and activities of the material. We are in constant sensory conversation with creation.

Fig. 33-35. Photos by author, building the outdoor tapestry frame and warping up, 2022

Woven relationships

Weaving, a process of overlapping long strips of a material in a pattern which 'locks' the materials together, is an important textile process to me. There are so many ways to weave, and so many potential outcomes. It's a process which has connected humans with the natural world for a long time. While a large portion of woven materials produced today are made from synthetic fibres by programmed machines, so many of our ancestors were caring for, cultivating, and harvesting plants, trees, and animals to weave with. Weaving is an interaction which deeply connects us to flora and fauna. When I first learnt how to weave, I was confronted with the reality of labour that goes into creating a woven textile by hand. There is firstly considerable planning, including making decisions about yarn, weaving tool, weaving style, draft type, thread count; so many factors to consider if you are looking to create a particular outcome. Then comes the labour of warping, setting up the fixed 'vertical' set of threads. Once the warp is on the loom we begin weaving the weft, the more versatile 'horizontal' threads. This whole process can take a day, to multiple years for one person to complete. Knowing this changed my perception of textiles. When I walk around a clothing store now, all I can think about is how much work was put into the resource extraction, textile processes, design, and creation of a $49.99 garment. Organisations like Fashion Revolution are raising awareness of unethical textile and fashion labour that allows those of us in Aotearoa to consume and waste the amount of textiles that we do. Fashion Revolution was organised after the 2013 Rana Plaza tragedy in Bangladesh, a preventable building collapse which killed over 1000 people and injured more than 2500. The annual Fashion Transparency Index was created by the organisation in response to this event in an effort to hold fast fashion brands accountable for being complicit in the working conditions that caused the Bangladesh tragedy. Conditions which continue to persist around the world. It reviews the public disclosure of human rights and environmental policies of the world's largest fashion brands and retailers ("Fashion Transparency Index"). While engaging in craft is so beneficial to human well being, the exploitation of craftspeople, garment workers, and many others along the supply chain is inhumane and unethical, causing pain and poverty around the world. This is another reason why creating localised material loops is so important. Local material ecosystems can be traced and held accountable to fair compensation of labour, humane working conditions, and appropriate resource consumption and wastage.

Tools like the Fashion Transparency Index provide a useful awareness of the realities of the global textile and fashion industries. The tools I offer through this project are less physical tools, and more design approaches. The example of creating woven relationships illustrates an awareness and learning about local resource systems, to engage in embodied craft experiences with local resources. At this stage I am not able to offer a definitive tick-box method or guidelines on how to achieve this. I don't believe we should explicitly define how to do this, as each ecosystem is so unique and complex that only active, reciprocal engagement can lead designers into symbiosis with their ecosystems. The tool is a multispecies philosophy approach. This is an openness to the realities of the others we exist alongside, a willingness to stay-with ecosystems, to practice-with materials over time, and to be-with materials in deep understanding of the physical reality, life cycles, and symbiotic relationships they enact. We come closer to real circular economies, real ecosystem symbiosis, through knowing and relationship building with what is around us.

Tapestry weaving is my chosen method of practising staying-with. It's like painting with yarns. Different yarn colours and textures can interact in three dimensional ways, creating a visual and textural depth. Over the last four years I have been practising a flow state style of tapestry weaving. I don't plan the outcome of the piece, I warp up a frame and weave. I began doing this as a mindful activity to improve my well being, and it certainly does improve it, but I also really enjoy the outcome of the pieces. I know they are influenced by my surroundings, my moods, and the textile process I feel like working with at the time. However, there is no need for me to prescribe an image or pattern onto the piece. It can be what it is, an exploration of texture, colour, and simply being. The first piece seen in figure 34 was made over a few years on an old screen printing frame. It is a warp of cotton, with a wool, cotton, and silk weft of creams, whites and greys and various yarn weights. Embroidery and lacing in natural silk and wool also feature. It is displayed on a stick covered in barnacles which I found at Kawakawa Bay. The tapestry is soon to be displayed in a house located in the bay. The second piece in this collection was made in 2021-22 (Fig. 35-36). It has a wool/flax warp. The weft includes wool of browns, greens, greys, undyed wool, and undyed silk. I also added silk embroidery and lacing. This piece was gifted to my grandparents. The similarities in these tapestries, which also came through in my larger tapestry for this project, are the wavy weft and spaces of exposed warp. Initially the weft was very flat but as I added weeds into it, the waves and exposed spaces began to come through. These features also invited textile events with insects and spiders.

This outdoor tapestry deepened my relationship with the smaller world of insects, spiders, other bugs, weeds, and the soil. Soil is an integral ecosystem to our survival as a species and is an ecosystem we must take particular care of. In Aotearoa, aside from forests and grasslands with woody biomass, annual soil losses are greater than natural rates of soil production (Donovan 12). In industries which rely on soils, such as farming, these losses could represent a loss of $20-110M annually (Donovan 12), not to mention the loss of biodiversity, and the ecosystems abilities to survive severe weather events. Again, this is not an offering of a physical tool or strict guidelines, but a process of approaching and understanding ecosystems in a meaningful way with the intention of reciprocity. I am grateful for the tools and knowledge that allow me to weave, but this is just what works for me and enables me to spend time understanding, observing, and learning about micro ecosystems and the small inhabitants we share this place with. Different designers with different embodied knowledge and craft expertise may approach staying-with ecosystems in different ways. As I build this relationship with soil, I contemplate why it is that at 25 I am only just beginning to deeply understand the importance of this 'underworld' ecosystem. Why is this important place not explored more in our education systems, and what is it that keeps us from relating our existence to the micro inhabitants of this place.

Many of us experience disgust in response to organisms like moulds, fungi, spiders, and insects. Many of these species live in close proximity to the ground, in grasses and within the soil. We seem to have quite the phobia of any life there, which is a bit weird. I guess a lot of us might have associated what goes on under the ground, with death. It's quite a confronting, for some fear inducing, reality. It doesn't have to be though. We should recreate our relationship with those underground dwellers who sometimes frighten us, because they're integral to our survival.

Fig. 34. Photo by author, Tapestry 01, 2023.

Fig. 35-36. Photo by Hannah Colenbrander, Tapestry 02 (and author's grandmother), 2023.

Fig. 37. Photo by author, tapestry details, 2023.

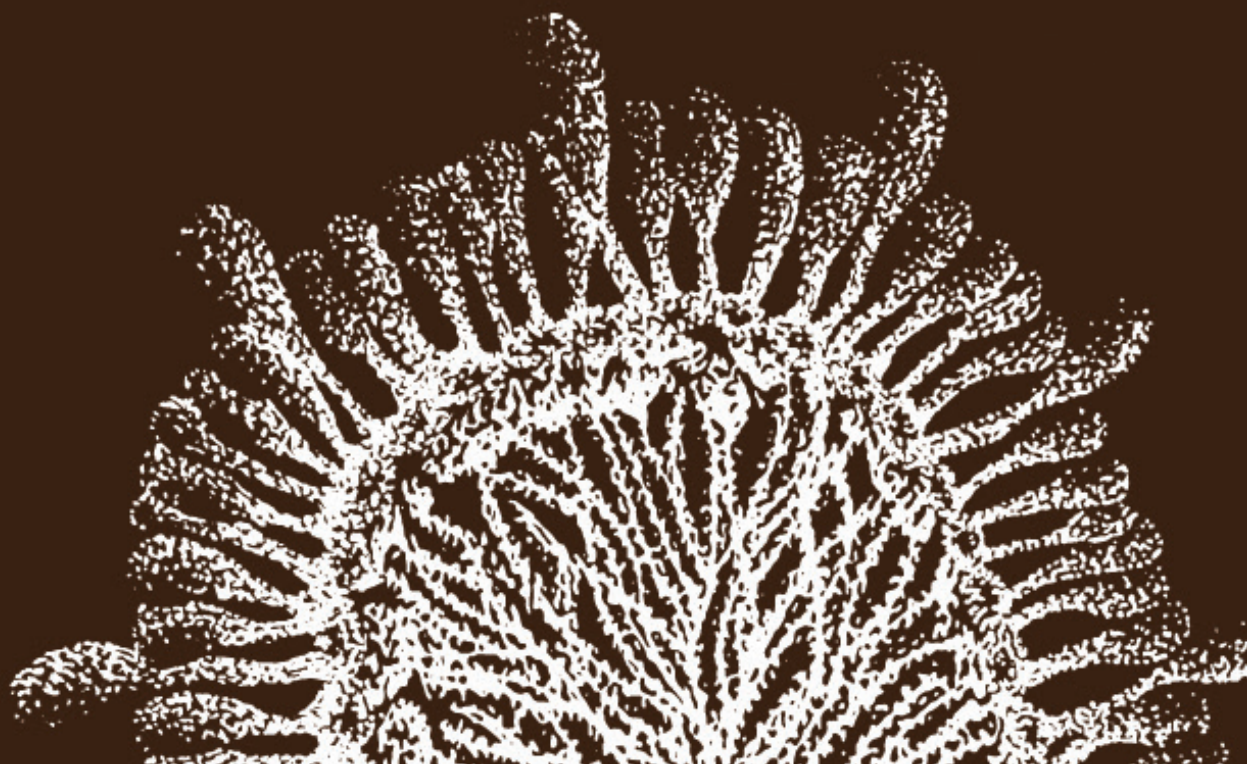
Photography: Breaking down disgust

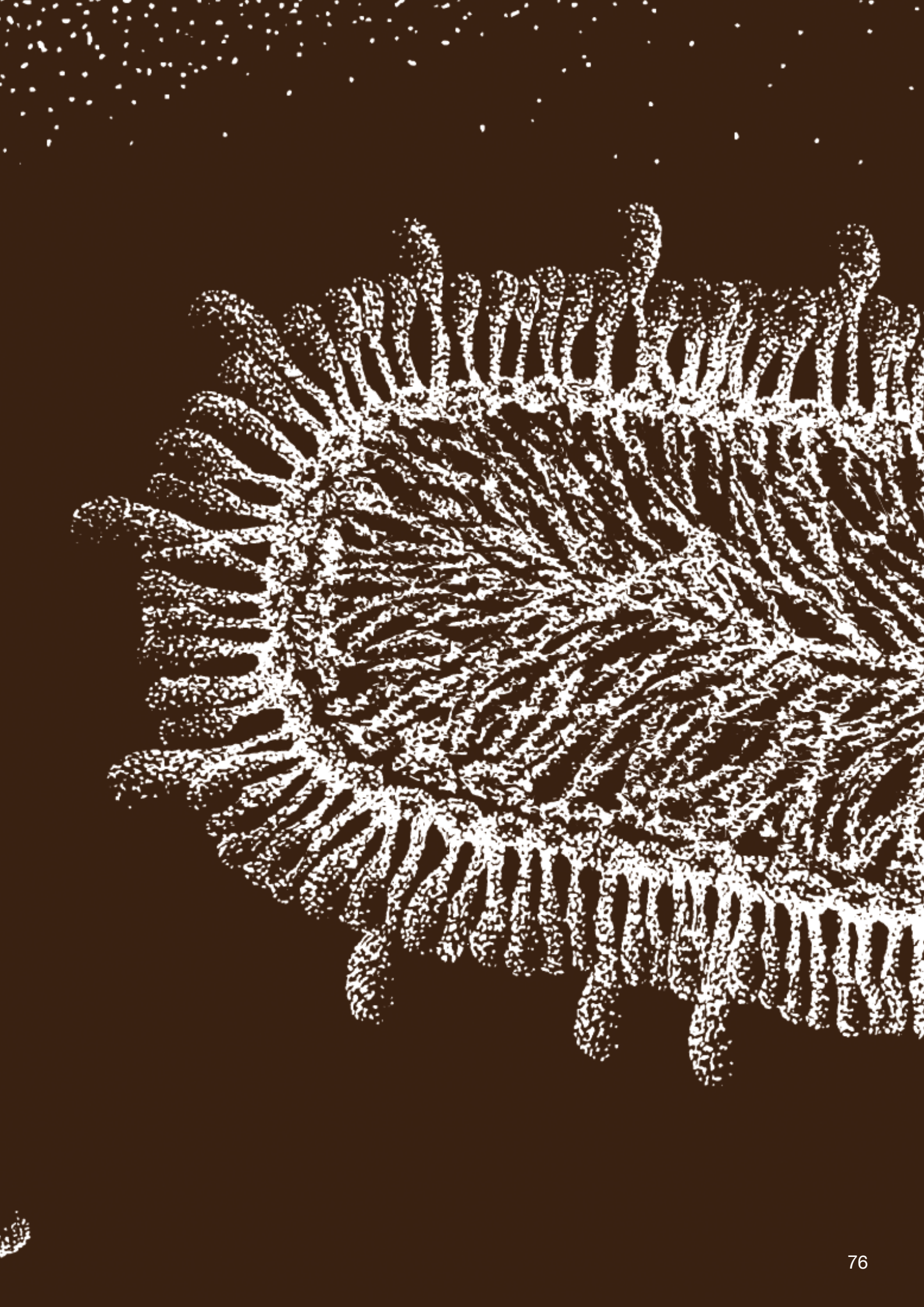
A common thread through my design work is to find beauty and aesthetics in uncomfortable or confrontational places. In this project we are confronting the reaction of disgust in response to waste, non-human others, and non-industrialised outcomes. Disgust is a sensory-emotional experience generally provoked by organic matter that is unpleasant to the senses and can manifest in very different reactions (Šinkūnas 233). Photography is employed in this project as a tool to communicate the many textile events that occur between myself, the woven tapestry, non-human organisms inhabiting the outdoor ecosystem, and interactions with mycelium in the lab ecosystem and outdoor ecosystems. The photographs captured in Textile Events allow us to reflect on the nature of our responses to non-human others, and prompt us to view them in lights we may not initially see them in i.e. as beautiful. How does it feel to sit with a large printed macro photo of an arachnid? What is your immediate response to moulds and fibrous fungi? This photographic book also illustrates the repetition of sustainable non-human forms. When I first laid eyes on mycelium fibres they immediately reminded me of fibres I've worked with before; particularly of felting wool. Parallels are also made between spider webs and mycelium, and fungi fruits and insects.

While I find the aesthetics of mycelium, spiders, and insects beautiful, there are many people who respond to these organisms with fear and disgust. Maria Walker explored disgust and other senso-aesthetic responses as barriers to the uptake of mycelium materials in architecture. Much like the textile and fashion industries, architecture is tethered to industrial standardisation and an expectation for permanence. Walker invites the industry to adopt a new materialist paradigm that values and engages materials' agency and multi-sensory, psychophysiological impacts (5). Some of us express disgust with displays of revolt and retraction from the source of our disgust. Others further engage with a disgusting source out of morbid curiosity (Walker 113-114). Similar neural regions are engaged when either form of disgust is expressed (Oosterwijk et al. 2). Through a survey in which participants had the opportunity to interact with mycelium bio-composites, Walker found that touching and engaging with the materials eased participants' discomforts about the materials' performance in architectural contexts (257). If we are able to stay-with an uncomfortable sensory experience, we often find it is not as bad as our initial reaction makes it out to be.

Fig. 38. Photo by author, spider co-designing outdoor tapestry, 2023.

05
Conclusion





This exegesis explored the project journey and research question ‘What is an ecosystem to the material and the maker?’ through a multispecies philosophy lens. This question interrogates our position as designers in both wild and human dominant ecosystems, and asks us to imagine the perspectives of organisms that we extract for material use and inhabitants of the environments we create within. Through mycelium material exploration, grounded in multispecies philosophy, I have provided autoethnographic examples of how designers can create symbiotic material connections. This project does not offer a prescribed outcome of materials or tick-box process for practising multispecies philosophy in design. The design route each designer takes is dependent on a particular place, time, and the “crossroads of agencies” within their ecosystem and themselves (Akómoláfé). In the ecosystem of Aotearoa, our human-material relationships are wasteful and hurtful to both human and non-human inhabitants. While aspirations exist to reform the design and use of materials, little systemic change has been made to better manage waste, to empower designers to design sustainably, and to empower consumers to build healthy material relations. Our culturally ingrained fears of death, decay, and retractive disgust responses, inhibit these integral systemic changes from being realised.

This project set out to respond to the necessity of moving human activities away from extractive linear resource systems and towards circular economies and ecosystem symbiosis. Through co-design with mycelium in the lab environment we found that human dominant spaces generally reinforce models of design that prioritise benefits to humans. The birds eye view concept of a circular economy is an important, but obscure and overwhelming goal. To ground this pathway, designers need to explore localised waste, resource, and textile processes to design connections between them, and create systems of symbiosis. It is also important to broaden our perceptions of what resources can be, taking a closer look at what is considered waste in our environments and how this waste might be transformed. Grounding the design of local systems in multispecies philosophy ensures that we design for daily human needs, while also benefiting non-human others within the ecosystem, who we ultimately rely on for collective survival.

Forming symbiotic relationships with fungal mycelium is one route to creating localised circular textile solutions. Flora, fauna, and funga are inherently intertwined across Aotearoa’s ecosystems and beyond, this includes us. To act in harmony and symbiosis, we can form relationships with fungi at different points of their life cycle to meet some of our needs and the needs of other organisms. The Mycelium Material Process diagram (Fig 9) communicates potential points of design intervention in the life cycle of fungi for co-designing with mycelium for materials. In textile and material co-creation with fungi we can valorise agricultural, wood, and other waste products for temporal human use. The scale of these material relationships requires further interrogation, development, and reform of commercial and political systems in order to be considered as being-with, living-with, staying-with practices. A sustainable system reflects its own form, expanding and contracting in a repetitive pattern (Yunkaporta 43-60). To enact sustainable expansion and contraction it is necessary to redefine human relationships with death and decay, as these are unavoidable in sustainable systems.

Fig. 39. Photo by author, spider web detail, 2023.

Fig. 40. Photo by author, Turkey Tail mycelium, 2023.

To better understand multispecies philosophy and sustainable systems, we explored textile relations through tapestry weaving in an outdoor ecosystem. This practice of staying-with provides habitats for non-humans and a greater sense of well being and connectedness for human makers. Designers engaged in staying-with practices will notice the reflections of form in the creation of sustainable systems. When we weave with natural fibres we relate to the spider, and we see the spider's web reflected in mycelial forms (figures 39-40). All of these textiles are fibres organised with purpose and imbued with patterns of life and death - the never ending rotation of physical matter on this planet. As an artefact, the woven habitat prompts us to see both wild and unwild ecosystems as intertwined and equally important. Work of this nature confronts us to enact cultural shifts in our fear and disgust responses to non-human others.

In design academia it is important to consider the language and meaning we evoke in attempts to enact cultural shifts of understanding. As Walker points out, "if we wish to combat the climate crisis, it is imperative we detach from the divisive perception of human and non-human," (10). Modern academic English is often individualistic and categorical, detaching us from relating ourselves to a collective whole. While it may feel grammatically strange to some, the use of we, us and our as dual-first person pronouns allows us to better engage in responsibility for the collective ecosystem and mentally situate ourselves within the physical reality of an interconnected ecosystem, rather than as separate external individuals.

As a designer I will continue to spend my time creating small physical connections of symbiosis where it is necessary and possible within Aotearoa's ecosystems and potentially abroad as well. The ecosystem of Aotearoa itself is connected to the wider earth ecosystem by water, by air, and by global human movement and trade. I endeavour to continue exploring what it means to practise multispecies philosophy both as an individual maker/unmaker and as a collective species. Collaboration with other makers like Fin and Josef will be integral to moving forward in this space and developing material and ecosystem understandings. We will continue to develop our localised version of the Aléa method. I do believe mycelium materials have a place in Aotearoa ecosystems, and I will continue to challenge the commercial impacts of their production and consumption.

We explored varying levels of design appraoches through the multispecies philosophy framework set out by Svenja Keune. This investigation highlighted what a multispecies design approach looks like, and directed the project's course to explore what this means in textiles and materials design. We showed that this approach can be applied in new material processes, mycelium materials, and traditional processes, weaving. This appraoch guides designers to design in symbiosis with our environments, improving the well being of all ecosystem inhabitants. An ecosystem to both the material and the maker, is everything. Like fungi, we make and unmake the ecosystem, and the ecosystem makes and unmakes us.

Works Cited

Acres, Barton. “Species of Mushrooms Cultivated in NZ.” www.mycologic.nz/commonly-cultivated-species. Accessed 19 July 2023.

Akómoláfé, Báyò. “On Ontological Mutiny.” Interview conducted by Ayana Young. *For the Wild*, 338, 30 June 2023. open.spotify.com/episode/2I0QtiRzsTwMlE8I75tRON?si=35058b359e794509.

Albers, Anni. “Material as Metaphor.” *The Art/Craft Connection: Grass Roots or Glass Houses Panel*, 25 February 1982. https://www.albersfoundation.org/alberses/teaching/anni-albers/material-as-metaphor. Accessed July 6, 2023.

“The Aléa Method.” aleawork.com/the-alea-method. Accessed 26 June 2023.

Bak-Andersen, Mette. *Reintroducing Materials for Sustainable Design: Design Process and Educational Practice*. Routledge, 2021.

Bhatnagar, A, E Tamboli, and A Mishra. “Wastewater Treatment and Mycoremediation by P. Ostreatus Mycelium.” *IOP Conference Series: Earth and Environmental Science,* 775, no. 1, 1 June 2021. doi.org/10.1088/1755-1315/775/1/012003.

“BioFab | Mycelium Packaging | Auckland.” www.biofab.co.nz. Accessed 30 August 2021.

Blanchette, Robert A., Deborah Tear Haynes, Benjamin W. Held, Jonas Niemann, and Nathan Wales. “Fungal Mycelial Mats Used as Textile by Indigenous People of North America.” *Mycologia,* 113, no. 2, 4 March 2021, pp. 261–67. doi.org/10.1080/00275514.2020.1858686.

Casey, Bernadette. “The Textile Reuse Programme: Building Macro Circular Systems for Used Clothing.” *Journal of Textile Science & Fashion Technology,* 2, no. 5, 31 May 2019. doi.org/10.33552/JTSFT.2019.02.000550.

Casey, Bernadette, and Brian Johnston. “Recommendations to the New Zealand Government,” 2021.

Cassarino, Marica, Sina Shahab, and Sara Biscaya. “Envisioning Happy Places for All: A Systematic Review of the Impact of Transformations in the Urban Environment on the Wellbeing of Vulnerable Groups.” *Sustainability,* 13, no. 14, January 2021. doi.org/10.3390/su13148086.

Das, Sachitanand, Siddhanta Kumar Bisoyi, Debasis Pattnaik, and Seweta Srivastava. “Role of Cultivated Mushrooms in Bioremediation: A Review,” 2021.

Donovan, Mitchell. “Modelling Soil Loss from Surface Erosion at High-Resolution to Better Understand Sources and Drivers across Land Uses and Catchments; a National-Scale Assessment of Aotearoa, New Zealand.” *Environmental Modelling & Software,* 147, 1 January 2022. doi.org/10.1016/j.envsoft.2021.105228.

Fashion Revolution. “Fashion Transparency Index 2022” 14 July 2022. issuu.com/fashionrevolution/docs/fti_2022.

Folke, Carl, Stephen Polasky, Johan Rockström, Victor Galaz, Frances Westley, Michèle Lamont, Marten Scheffer, et al. “Our Future in the Anthropocene Biosphere.” *Ambio,* 50, no. 4, 1 April 2021, pp. 834–69. doi.org/10.1007/s13280-021-01544-8.

Haneef, Muhammad, Luca Ceseracciu, Claudio Canale, Ilker S. Bayer, José A. Heredia-Guerrero, and Athanassia Athanassiou. “Advanced Materials From Fungal Mycelium: Fabrication and Tuning of Physical Properties.” *Scientific Reports,* 7, no. 1, March 2017. doi.org/10.1038/srep41292.

Huotilainen, Minna, Mimmu Rankanen, Camilla Groth, Pirita Seitamaa-Hakkarainen, and Maarit Mäkelä. “Why Our Brains Love Arts and Crafts Implications of Creative Practices on Psychophysical Well-Being.” 18, 2018. doi.org/10.7577/formakademisk.1908.

Karell, Essi. “Closing the Loop through Clothing Design: Wishful Thinking or Achievable Practice?” School of Arts Design and Architecture, 2021. urn.fi/URN:ISBN:978-952-64-0409-7

Keune, Svenja. “Designing and living with organisms weaving entangled worlds as doing multispecies philosophy.” *Journal of Textile Design Research and Practice,* 9.1, 2021, pp. 9-30.

Lee, Jee-Yon, and Duk-Chul Lee. “Cardiac and Pulmonary Benefits of Forest Walking versus City Walking in Elderly Women: A Randomised, Controlled, Open-Label Trial.” *European Journal of Integrative Medicine,* 6, no. 1, 1 February 2014, pp. 5–11. doi.org/10.1016/j.eujim.2013.10.006.

Lewis, Simon L., and Mark A. Maslin. “Defining the Anthropocene.” *Nature,* 519, no. 7542, March 2015, pp. 171–80. doi.org/10.1038/nature14258.

Mills, Jacob G., Justin D. Brookes, Nicholas J. C. Gellie, Craig Liddicoat, Andrew J. Lowe, Harrison R. Sydnor, Torsten Thomas, Philip Weinstein, Laura S. Weyrich, and Martin F. Breed. “Relating Urban Biodiversity to Human Health With the ‘Holobiont’ Concept.” *Frontiers in Microbiology,* 10, 2019. www.frontiersin.org/articles/10.3389/fmicb.2019.00550.

Ministry for the Environment. “Ōhanga Āmiomio - Circular Economy,” 20 June 2022. environment.govt.nz/what-government-is-doing/areas-of-work/waste/ohanga-amiomio-circular-economy/.

“Misuse of Drugs (Industrial Hemp) Regulations 2006 (SR 2006/163) (as at 01 April 2020) Contents – New Zealand Legislation.” legislation.govt.nz/regulation/public/2006/0163/latest/DLM389407.html. Accessed 5 July 2023.

Mushroom Packaging. “About.” mushroompackaging.com/pages/about. Accessed 19 July 2023.

Mushroom Packaging. “Our Process.” mushroompackaging.com/pages/our-process. Accessed 5 July 2023.

Oosterwijk, Suzanne, Lukas Snoek, Jurriaan Tekoppele, Lara H. Engelbert, and H. Steven Scholte. “Choosing to View Morbid Information Involves Reward Circuitry.” *Scientific Reports,* 10, no. 1, 17 September 2020. doi.org/10.1038/s41598-020-71662-y.

“Our Story - Velcro Companies History.” Velcro Brand. www.velcro.com/original-thinking/our-story/. Accessed 4 July 2023.

Oyanedel, Rodrigo, Amy Hinsley, Bryn T.M. Dentinger, E.j. Milner-Gulland, and Giuliana Furci. “A Way Forward for Wild Fungi in International Sustainability Policy.” *Conservation Letters*. doi.org/10.1111/conl.12882.

Perrot, Jean-François, and Alison Subiantoro. “Municipal Waste Management Strategy Review and Waste-to-Energy Potentials in New Zealand.” *Sustainability,* 10, no. 9, September 2018. doi.org/10.3390/su10093114.

Pöllänen, Sinikka. “Elements of Crafts That Enhance Well-Being.” *Journal of Leisure Research,* 47, no. 1, 1 March 2015, pp. 58–78. doi.org/10.1080/00222216.2015.11950351.

“Polymer” *Britannica.* https://www.britannica.com/science/polymer. Accessed July 18, 2023.

Rhodes, Christopher J. “Mycoremediation (Bioremediation with Fungi) – Growing Mushrooms to Clean the Earth.” *Chemical Speciation & Bioavailability,* 26, no. 3, January 2014, pp. 196–98. doi.org/10.3184/095422914X14047407349335.

“Fungal Life Cycles - Spores and More.” *Science Learning Hub – Pokapū Akoranga Pūtaiao*, University of Waikato. www.sciencelearn.org.nz/resources/2664-fungal-life-cycles-spores-and-more. Accessed August 30, 2021.

Simard, Suzanne W. “Mycorrhizal Networks Facilitate Tree Communication, Learning, and Memory.” *In Memory and Learning in Plants*, edited by Frantisek Baluska, Monica Gagliano, and Guenther Witzany, Springer International Publishing, 2018, pp. 191–213. doi.org/10.1007/978-3-319-75596-0_10.

Šinkūnas, Tomas. “Hidden Foundations of Disgust: Reevaluating the Existential Nature of Disgust.” *Horizon,* 6, no. 2, 2017, pp. 226–49.

Stamets, Paul. *Mycelium running: how mushrooms can help save the world.* Ten Speed Press, 2005.

Stamets, Paul. *Fantastic Fungi.* Simon and Schuster, 2020.

Wallner, Peter, Michael Kundi, Arne Arnberger, Renate Eder, Brigitte Allex, Lisbeth Weitensfelder, and Hans-Peter Hutter. “Reloading Pupils’ Batteries: Impact of Green Spaces on Cognition and Wellbeing.” *International Journal of Environmental Research and Public Health,* 15, no. 6, June 2018. doi.org/10.3390/ijerph15061205.

Wohlleben, Peter. *The hidden life of trees.* Greystone Books, 2016.

Yunkaporta, Tyson. *Sand talk: How Indigenous thinking can save the world.* Text Publishing, 2019.

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