

# Hannah-Lee Turner

Exegesis Masters of Art and Design AUT

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# Refining through Digestion

*Fruiting hope with mycelium's power to process our textile waste*



A thesis submitted to Auckland University of Technology in partial fulfilment of the requirements for the degree of Master of Design.

## Abstract

'Refining through Digestion' is an exploration in material design that involves collaborating with organisms capable of converting textile waste into a circular system. The research investigates how a practice-led design approach utilises biomimicry, biomaterial, and bio-collaboration to reduce our textile waste resolve and increase circularity through alternative, biological systems of waste recycling. This endeavour offers solutions for creating new material hybrids and/or facilitating the degradation of fibers.

Through experimentation and speculation, I conducted trials cultivating mycelium under various conditions and observed how textile waste feeds (such as polyester, cotton and a polyester wool blend) interacted with this process. These observations aided the refinement of mycelium growing methods. The process yielded a material with potential applications for artistic, architectural and agricultural practices, as well as industrial settings. My focus was on artistic design of an installation that can evoke hope through the resilient, adaptive sensibility of mycelium, as well as a proposition for a new biomaterial. Collaborating with living organisms opens avenues for exploring possibilities beyond mere product outputs. It fosters a deeper consideration of resources and contributes to the development of sustainable outcomes. By reconnecting and recalibrating our relationship with biological systems, we pave the way for applying these insights to future materials and practices.

Cover image:

Turner, H. L., *Phoenix oyster mushroom in post-consumer polyester fibre*, 2023, HLJ Studio, Tāmaki Makaurau

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**Attestation of Authorship :**

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the Acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

Signed ; Hannah-Lee Turner

3 May 2024

## **Disclaimer**

This research project aims to plant hope and hypothesize on future materials. Equally, the research could lead to some promising new questions. The overarching result is a fruit of hope, not a scientifically tested material. An important guiding principle is the consideration of the organisms engaged in this research. The intention is to work gently in collaboration with the organisms. Symbolically the organism fruiting assured the continuation of using waste fibres for the research, though I have no formal research to validate the organisms contentment in this project. I therefore do not consider or advocate this to be formal evidence to support growing mycelium or mushrooms on or in environments they do not 'enjoy'.

Dedicated to ;

Papatūānuku – the earth mother

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I acknowledge and stand with Toitū Te Tiriti – Honouring Aotearoa's Treaty of Waitangi.

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## Glossary

**Animism** - the attribution of a living soul

to plants, inanimate objects, and natural phenomena.

**Bio-collaboration** - a design strategy created with living organisms and humans.

**Biomimicry** – the design and production of materials, structures, and systems that are modelled on biological entities and processes.

**Biophilia** - an innate and genetically determined affinity of human beings with the natural world.

**Bioremediation** – the use of either naturally occurring or deliberately introduced microorganisms to consume and break down environmental pollutants, in order to clean a polluted site.

**Bioterrial** – A material that uses the growth of an organism or organisms in its manufacture. Coined by Chris Maurer of Redhouse Architecture. (USA)

**Hyphal**- each of the branching filaments that make up the mycelium of a fungus.

**Fruiting** – the process of mycelium growing a mushroom – the physical mushroom is the fruit. This occurs when mycelium is exposed to oxygen.

**Mycelium** – the root system before the mushroom fruits.

**Prealm** – a word I coined for the process of evolving through, moving forward with reflection – place – realm.

**Substrate** – the food source substance that the mycelium lives off.

# Introduction

*To provoke new ways of thinking; Resilience and adaptation of mycelium.*

In the year 2000 the world nervously celebrated the millennium, the excitement of leaving the 90s and the nervousness of entering a deepening computer age. At the age of 7, as environmentalism surrounded me, I entered Trash to Fashion, with a dress made by weaving together plastic bags from *New World* supermarkets. I was strongly aware of the waste we were producing.

Ever since then working with waste has become a design factor in my process. In my first collection, (London 2011), designs were dictated by off-cuts I found in manufacturer's dumpsters. After running my label and artist shop in New Zealand, I moved to Berlin where I worked for a fashion label where I directly experienced the issues of waste in the garment-making process. I also became aware of the issues of farming, chemicals and resource waste in processing materials. Though the design philosophy was innovative and conceptually progressive, innovative production was not adopted. Working in Berlin-based, Argentinian artist Tomás Saraceno's studio was an exciting turning point in the role of art making for public spaces that speak to political and environmental importance; making large-scale artworks that could fly with solar energy across borders.<sup>1</sup> Back in Aotearoa, while I reconnected to nature and its intricate systems, I found language and storytelling that supported my world view through Robin Wall-Kimmer, a Potawatomi author and botanist, and my curiosity in textile waste continued to fuel my fashion label. This led to the search for positively impactful ways to utilize this resource, thus prompting the undertaking of this research.

In 2023, I began to celebrate the wondrous nature of mycelium and other natural organisms, recognising their resource efficiency. Chapter One introduces seminal authors including co-founder of the Biomimicry Institute Janine Benyus's *Biomimicry Innovation inspired by Nature* (1998) and David Sánchez-Ruano (2016), *Designing with-in Nature* introduced me to the language and methods of biomimicry and animism. A speculative approach is inspired by feminist academic Donna Haraway who reinvigorated the value of opposed storytelling to the deadly destruction of the planet.<sup>2</sup>

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<sup>1</sup> "Aerocene", - Studio Tomás Saraceno, 2018, <https://studiotomassaraceno.org/aerocene/>

<sup>2</sup> Donna Haraway *Story Telling For Earthly Survival*, n.d., <http://archive.org/details/donna-haraway-story-telling-for-earthly-survival..>

The first two chapters in this thesis also dive into a philosophy of hopefulness. Chinese-American anthropologist Anna Tsing, asks how can nature re-pave the way through non-serving systems exemplified by the legacy and current reality of Colonial-Capitalism.<sup>3</sup> She provides a perspective on how mushrooms can and are a symbol of hope. This connects to my thesis title; *Refining Through Digestion, Fruiting of Hope - Mycelium's Power to Process our Textile Waste*.

The practice-led approach in this thesis is introduced philosophically in Chapter Two, and outlined in practice in Chapters Three and Four. The approach used is bound to the methods of designer and former MIT Professor Neri Oxman's research *Material Ecology*. I experienced her innovative material exhibition at the Melbourne Triennial Art Show 2017. Her exploration of biomaterial and conceptual desire to grow buildings the way that a tree would, regeneratively and resource efficiently, has led to my exploration through observing and experimenting with natural systems.<sup>4</sup>

My hope for our planet resurfaced through encountering recycling material companies, mycology and witnessing the large fruiting of native phoenix oyster mushrooms grown in textile waste. In this thesis, you can share the optimism in biomaterial possibilities through my experiments.

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<sup>3</sup> Anna Lowenhaupt Tsing, *The Mushroom at the End of the World*, (Princeton, NJ: Princeton University Press, 2015).

<sup>4</sup> Neri Oxman, "Material-Based Design Computation" (PhD thesis, Massachusetts Institute of Technology, 2010) <https://dspace.mit.edu/handle/1721.1/59192>; "'Vespers' – a Series of Stratasys 3D Printed Death Masks Designed by Neri Oxman and Her Team – Highlights at Prestigious National Gallery of Victoria," *Business Wire*, *Leonardo* 56, no. 6 (December 1, 2023): 606–12. [https://doi.org/10.1162/leon\\_a\\_02431](https://doi.org/10.1162/leon_a_02431); "Material Ecology," *The Dirt*, August 20, 2009, <https://web.archive.org/web/20110718021252/http://dirt.asla.org/2009/08/20/material-ecology/>.



Figure 1. Turner, H. L., *Native phoenix oyster mushrooms grown in textile waste*, 2023, HLJ Studio, Tāmaki Makaurau

## Chapter 1: The Web of Hope



Figure 2. Turner, H. L., *Hypha and mycelium growing in textile waste*, 2023, HLJ Studio, Tāmaki Makaurau

The contextual knowledge for this research draws from a diverse range of disciplines, weaving together theories of speculative design, leading industry textile environmental impact reports, material innovation and artistic practices within the approaches to material innovation that apply biomimicry methods.

My research references the theories of ecological feminist Donna Haraway and anthropologist Anna Tsing. In *Staying with the Trouble* (2016), Haraway presents the hierarchical dominance of the humans over nature in the time of the Anthropocene, which she terms the Chthulucene, a time of making-with nature.<sup>5</sup> Her theory informs my approach to observation and collaboration with mycelium in my research experiments. In Anna Tsing's book *The Mushroom at the End of the World* (2015), she poetically notes the potential for co-existence and survival amid growing environmental and political crises, highlighting the resilience, adaptability, and unity embodied by the matsutake mushroom.

Biomimicry also resonated with Haraway's research, which references concepts of blending boundaries to form unions between nature and human technology in the time of environmental crisis. Biomimicry, coined by Janine Benyus is a method and a methodology. Design methods in this paradigm mimic how nature works and utilise the genius of the systems it operates in.<sup>6</sup>

Textile environmental impact and harm reports also drives my quest for solutions in this research. Global statistics are analysed in the report by Ellen MacArthur Foundation making it imperative that we adopt circular systems.<sup>7</sup> The report *Understanding of Bio Material Innovation* (2020)<sup>8</sup> highlights the urgent need for bio materials; an umbrella term for expanding innovation in this field.

In the book *Bio Design* (2012)<sup>9</sup> the concept 'vital design' explores the potential of design with biology, and live organisms impact on production, materials and systems. Jane Scott, Neri Oxman, Jo Bruznyksa and collaborative project the *Fungi-mutarium* all experiment with the perception of nature's high value, in their innovative material research and design propositions, to create artworks that speak to these blending relationships.<sup>10</sup> They applied the methods of biomimicry in their investigation on patterns, processes and operation systems, in which nature has millions of years of experience.

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<sup>5</sup> Donna Haraway, *Staying with the Trouble - Making Kin in the Chthulucene* (Durham, London: Duke University Press, 2016).

<sup>6</sup> Janine Benyus, *Biomimicry: Innovation Inspired by Nature* (New York: Perennial, 2009)..

<sup>7</sup> Ellen MacArthur Foundation, "A New Textiles Economy: Redesigning Fashion's Future,." (Ellen MacArthur Foundation), <https://www.ellenmacarthurfoundation.org/a-new-textiles-economy>.

<sup>8</sup> Dr. Amy Congdon et al., "Understanding 'Bio' Material Innovations: A Primer for the Fashion Industry,." (Biofabricate & Fashion for Good, 2020), <https://reports.fashionforgood.com/wp-content/uploads/2020/12/Understanding-Bio-Material-Innovations-Report.pdf>.

<sup>9</sup> William Myers, *Bio Design: Nature, Science, Creativity*. (New York, NY: Museum of Modern Art, 2018).

<sup>10</sup> Oxman, "Material-Based Design Computation.;" responsiveknit. "Programmable Knitting." June 9, 2015. <https://responsiveknit.com/programmable-knitting/>; "Jo Burzynska." RM Gallery, Accessed April 19, 2024. <https://rm.org.nz/jo-burzynska/>.

## Design in a broken age of capitalism

Both Haraway and Tsing acknowledged the problematic systems of capitalism for our collective natural and human environments. They explore new perceptions of storytelling and hope for ways to thrive in this world. Through my creative work I intend to instil hope and dreams of alternative ways to honour our ecosystem. Although identifying textile waste issues, the focus is on innovation rather than the destruction of our planet.

In *Staying with the Trouble* (2016) Haraway emphasized the importance of challenging societal and capitalist norms by imagining alternative worlds and frameworks that foster better ways of coexisting. Haraway reflected on human and non-human social structures, offering a critical perspective on the Anthropocene and introducing the concept of the Capitalocene as an alternative. Haraway identifies the interconnectedness and inter-reliance of all life forms. She asks: "What happens when a partner involved critically in the life of another disappears from the earth?... This kind of question has to be asked in the urgencies of the Anthropocene and Capitalocene if we are to nurture arts for living on a damaged planet."<sup>11</sup> The breakdown of these symbiotic relationships highlights the urgency of addressing environmental degradation and the need for collaborative efforts to protect and restore our damaged planet. Haraway's imaginative way of evaluating the world is expressed through the diversity of storytelling. Through her re-wording Haraway re-words, creating tangible concepts for necessary adoption for a resilient future.

Haraway's speculative thinking and storytelling resonate with this research's processes and goals. As an environmentalist, I am discouraged by ongoing human impacts on our planet, hindering my growth. Exploring new storytelling methods aligns with biomimicry and speculative inquiry, influenced by my biophilic upbringing. I also identify with the concept *sympoiesis*, because I *make-with* organisms, entering a collaborative role with mycelium and textile waste.<sup>12</sup>

In *The Mushroom at the End of the World* (2015), Tsing poetically explores the matsutake mushroom's resilience amid environmental and political crises, delving into its world, the lives of pickers, trading, war impacts, and capitalism's effects on human and non-human communities. She presents the mushroom as a metaphor for hope and resolution. Tsing writes: "When Hiroshima was destroyed by an atomic bomb in 1945 it is said the first living thing to emerge from the blasted landscape was a matsutake mushroom."<sup>13</sup> Through stories of individuals, she sheds light on the nuanced complexities of survival, particularly for refugees and veterans seeking comfort in the *simplicity* of forest living. Tsing's observations offer a nuanced perspective on resilience and survival strategies within the complex economic landscape dominated by capitalism.

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<sup>11</sup> Haraway, *Staying with the Trouble*, 69

<sup>12</sup> Haraway, 58

<sup>13</sup> Tsing, *The Mushroom at the End of the World*, 2015, 3

Biomimicry, coined by Janine Benyus in 1997, is widely practiced across disciplines, notably in design and engineering. The Biomimicry Institute's database, *Ask Nature*, collects resources for emulating nature's methods.<sup>14</sup> Biomimicry, which consists of the words "bio" (life) and "mimicry" (imitate), refers to the close observation of how nature operates and in this sense regards nature as teacher. The following is a poem by Janine Benyus:

*Nature runs on sunlight  
Nature uses only the energy it needs  
Nature fits form to function  
Nature recycles everything  
Nature rewards cooperation  
Nature banks on diversity  
Nature demands local expertise  
Nature curbs excess from within  
Nature taps the power of limits<sup>15</sup>*

Also inspiring this research is the way spiders and wasps build their homes through digesting proteins and extruding into refined fibres as described by scientists and designers alike, such as Arakawa et al. and Pourali et al.. For example the paper wasp processes wood into a pulp through its saliva, building a nest. These concepts became a template when considering efficient ways to process 'new material' from waste.<sup>16</sup>

In this sense, biomimicry provides theoretical support, celebrating nature and fostering hope. This research will utilize biomimicry strategies to enhance efficiency, minimize resource use, and reduce ecological impact by employing fewer materials, resources, and energy, thus generating less waste.

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<sup>14</sup> "About." AskNature, Accessed June 6, 2023. <https://asknature.org/about/>.

<sup>15</sup> Benyus, *Biomimicry*, 7

<sup>16</sup> Selda Pourali, Hadi Seyednouri, and Maziar Asefi, *Investigation of Paper Wasp Nest for Inspiration in Architectural Technologies*; . "Spider Web Is Strong and Elastic, — Biological Strategy — AskNature" AskNature, Accessed November 1, 2022. <https://asknature.org/strategy/spider-web-is-strong-and-elastic/>; "Nests Made of Paper, — Biological Strategy — AskNature." AskNature, Accessed April 19, 2023. <https://asknature.org/strategy/nests-made-of-paper/>; Materials: The Secrets of Spider Silk, (Teachers TV/UK Department of Education, 2009), online <https://video.alexanderstreet.com/watch/materials-the-secrets-of-spider-silk>Materials; Kazuharu Arakawa et al., "1000 Spider Silk Comes,," *Science Advances* 8, no. 41 (October 12, 2022): eabo6043; Abascal, Nadia C., and Lynne Regan Abascal and Regan, "The Past, Present and Future of Protein-Based Materials,," *Open Biology* 8, no. 10 (October 31, 2018): 180113.

## Industry reports; *The agency of biomaterials*

The quest for better material solutions is influenced by global reports on textile impact on the environment. Statistics analysed in the report *A New Textile Economy* by the Ellen McArthur Foundation in 2017 framed the urgency to adopt more resourceful methods when producing and disposing materials. In 2015 the global closed-loop of recycled garments was less than 1%.<sup>17</sup> Recognising the resource value in the 'end of life' of textiles and or garments is urgent and calls for further innovation.

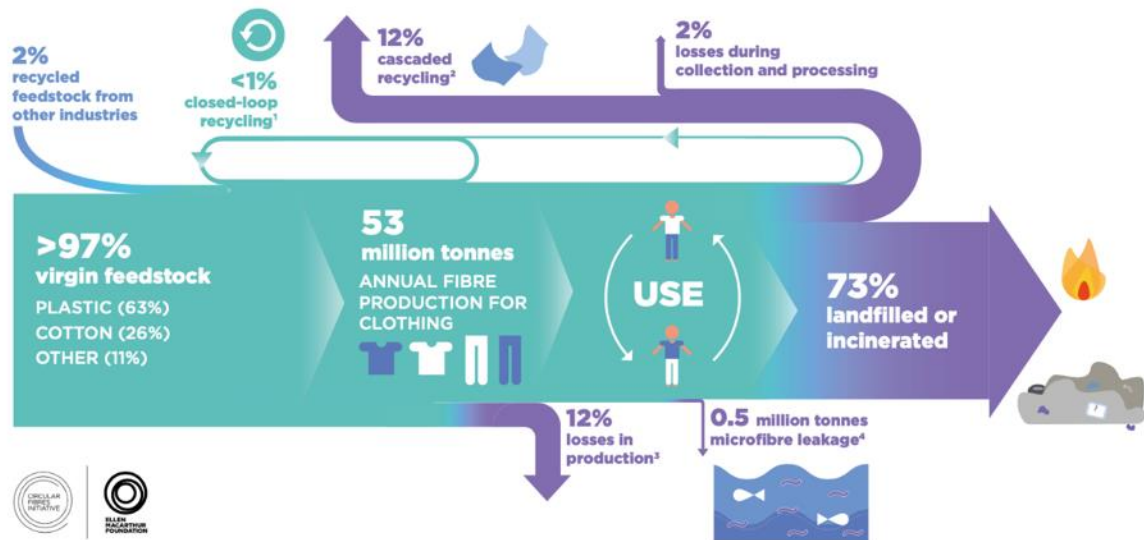


Figure 3. Ellen McArthur Foundation, *Global Materials Flow 2015, 2017*, <http://www.ellenmacarthurfoundation.org/publications>.

<sup>17</sup> Ellen MacArthur Foundation, "A New Textiles Economy."

Biomaterial as an umbrella term is categorised into different sub terms; biobased, biosynthetic, biofabricated ingredients, and bioassembled according to the processes used and sustainability. The report *Understanding Bio Material Innovations (2020)* unpacks the evolution of biomaterial and identifies how this name has been used. It is important to understand the differentiation due to the resources and processes that take place to create them. Congdon et al. suggest that “Critically, the name attached to any material doesn’t change how it has been made, its impacts, or its end of use. This is why bio terms applied to a product shouldn’t only be taken at face value. It is essential to go a level deeper in order to understand each specific material’s process”.<sup>18</sup>

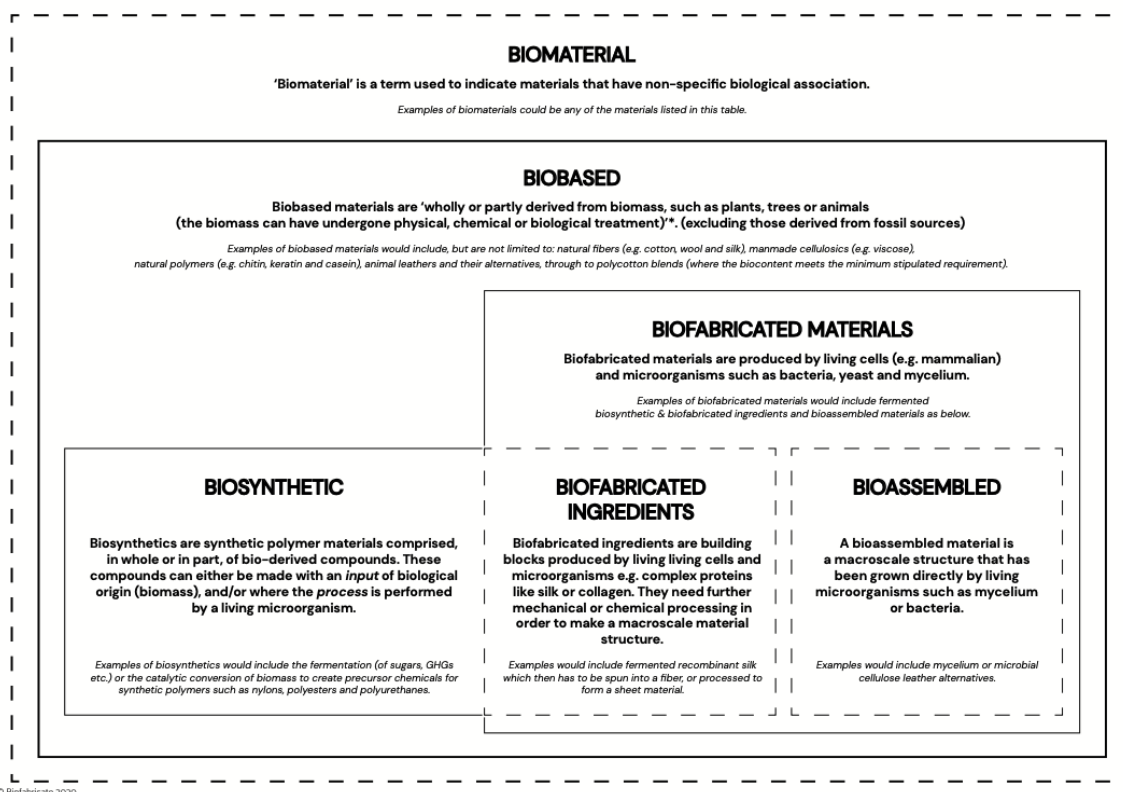


Figure 4. Understanding ‘Bio’ Material Innovations, *Defining Bio, 2020, Understanding-Bio-Material-Innovations-Report.*

<sup>18</sup> Congdon et al., *Understanding ‘Bio’ Material Innovations*, 6.

The exclusive ownership of innovations arising from material research may present obstacles to their widespread adoption and subsequent acceptance in the market, consequently impeding their overall advancement. In this report an examination of industrial-scale material products was conducted, which included the analysis of micro silk by *Bolt Threads* and *Mylo*, a mycelium-based leather substitute.<sup>19</sup> The development of *Bolt Threads*' micro silk fibre is aimed at replicating the strength and performance characteristics of spider silk. Despite decades of efforts by bioengineers and scientists to create a commercially viable replica, achieving this goal remains a longstanding challenge.<sup>20</sup> While the demand for high-performance materials persists, driven by ongoing technological advancements, polyester continues to maintain its dominance in the industry. However, there is a discernible positive trend towards the utilisation of biomaterials, driven by environmental considerations and sustainability objectives. Nevertheless, it is imperative to address the challenges associated with the degradation processes of existing petroleum-based fibres, requiring resolutions in material development practices.



Figure 5. Turner, H. L., *Spider silk captured in morning sunlight*, 2023, Tāmaki Makaurau

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<sup>19</sup> About Us,” Bolt Threads, accessed November 29, 2022. <https://boltthreads.com/about-us/>; “Meet Mylo™.” Mylo, accessed November 23, 2023. <https://mylo-unleather.com/>.

<sup>20</sup> *Materials*.

Steve Job's statement on the back cover of *Bio Design* by William Myers (2012) reads: "The biggest innovation of the 21st century will be the intersection between technology and biology." The book showcases the future of design examples that integrate nature's systems and technologies to solve new material challenges. In the introduction of *Bio Design*, Paola Antonelli explains how what was once a speculative design collaboration with biology is now increasingly becoming manufacturable realities. She reinforces the idea that bio-designs could have a positive effect on a global scale, yet they still require increased funding and public recognition to realise their application and global impact. This book focuses on hope-filled designs that utilise the genius of nature's systems, encouraging further material experimentation in this research. It supports the desire and the global requirement to examine these designs for scalability and applicability in the industry. Antonelli notes that "if our relationship with nature is broken, this book makes us hope that perhaps we will be able to fix it from within."<sup>21</sup>



Figure 6. Klarenbeek, E., *Mycelium Chair* 3D-printed with living fungus, 2013, <https://www.biology-design.com/>

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<sup>21</sup> Myers, *Bio Design*. 7

## Artistic practice; Collaborative growth

Artists Neri Oxman, Jane Scott, Jo Burzynska and the Fungi-Mutarium are reimagining relationships with materials and organisms through collaborative and conscious works that address the environmental crisis. They bridge the gap between speculative industrial technology and the potential applications of materials, particularly Oxman and Scott, at an architectural scale. Their work delves into the processes of biomimicry, focusing on resourcefulness and energy efficiency in building design. In the predominately textile-knitted works produced by artist Jane Scott, she investigates the possibilities of structures and fibres collaborating to rethink built spaces. In the work *Bioknit* (2022), Scott led a research project on knitted structures that were filled with inoculated mycelium substrate which allowed the mycelium to grow through the knitted forms causing a structurally sound pavilion.

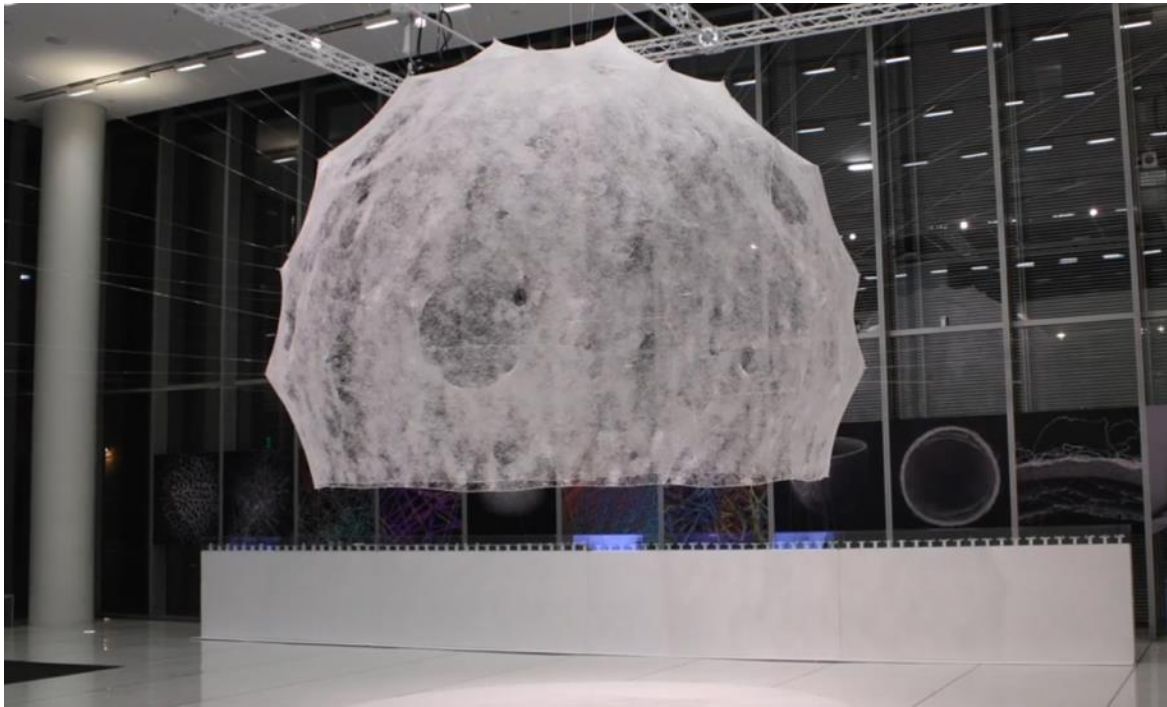


Figure 7. Oxman, N., *Silk Pavilion I*, Media Lab, Co-Fabrication, 2013, Massachusetts Institute of Technology, Massachusetts.

Scott's earlier work *Programmable Knitting: An Environmentally Responsive Shape Changing Textile System* illustrated the potential of natural systems with organic materials that could be applied into an architectural space as environmentally responsive textiles. Working within a biomimicry methodology, particularly hydromorphic systems, she created future material innovations that responded to changes in environmental humidity by changing swelling and shrinking due to the knitted geometry like cellular structure of wood.<sup>22</sup> These works inform technical solutions and visions to the architectural materials industry and they push the boundaries of technology and nature in collaboration.<sup>23</sup> In the context of design and architecture, Oxman states like nature she wants to create "solutions with maximal performance using minimal resources."<sup>24</sup> This is well illustrated in her *Silk Pavilion*, where she reimagines how to make a silk and build a structure. As opposed to traditional methods of silk manufacturing where the silk worm are boiled killing them to extract the silk fibre, Oxman instead designed a structure that could collaborate with the worms to form a woven pattern by allowing them to move and secrete the silk in natural ways that created a silk canopy of fabric. The final result was a structured shelter. This work illustrates the potential in resource efficient and collaborative environmentally friendly processes for building structures and materials.



Figure 8. Scott, J., *Bioknit, Hub for Biotechnology in the Built Environment*, 2023, Newcastle University, Newcastle, 10.3389/fbioe.2023.1229693.

<sup>22</sup> "Jane Scott,," responsiveknit, accessed June 9, 2023. <http://responsiveknit.wordpress.com>.

<sup>23</sup> "Is Furniture Made from Fungus the Future?" Newcastle University, accessed November 25, 2023. <http://www.ncl.ac.uk/press/articles/archive/2022/10/bioknit/>.

<sup>24</sup> Oxman, "Material-Based Design Computation."

Dr. Jo Burzynska, a local Aotearoa-based artist and researcher, explores connections and understandings that can be made between people, culture, nature, and place.<sup>25</sup> Burzynska exhibited her work 'Hyphal Space' (2023) at Room Gallery in Tāmaki Makaurau, Auckland. 'Hyphal' refers to the stem from which the fruiting mushroom appears. The space celebrates the multiple potentials in which the fungi kingdom can be revered. In a poetic environment, she illustrated mycelium brick-like forms, acknowledging the local packaging company *Biofab*.<sup>26</sup> The mediational space takes the form of the Aotearoa-New Zealand native basket fungi which fruit post-thunderstorm. Army bags filled with fruiting mushrooms pay homage to the science showing that differing mycelium species can coexist in the same spaces without attacking or taking over.<sup>27</sup> This work resonates with political and environmental considerations that frame hope for a future in symbiotic relationships from which we can learn from and cultivate, particularly with fungi.

The *Fungi-Mutarium* (2014), created by Katharina Unger and Julia Kaisinger and supported by Utrecht University Netherlands, is a conceptual device that incubates mycelium to transform waste plastic into edible treats.<sup>28</sup> Following extensive sampling and research with fungi, they devised a solution where mycelium converts toxic plastic into an edible product. The concept seeded the idea for home plastic recycling through mushroom cultivation. This work evoked research into the application of textile waste as a substrate for mycelium to thrive in and potentially support the degradation process.

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<sup>25</sup> "Jo Burzynska."

<sup>26</sup> "BioFab | Mycelium Packaging | Auckland,," BioFab, accessed March 30, 2024. <https://www.biofab.bio>.

<sup>27</sup> Barton Acres, *Growing Gourmet Mushrooms at Home (Mycologic, 2023)*,

<sup>28</sup> "Fungi Mutarium," L I V I N, Accessed August 23, 2023. <http://www.livinstudio.com/fungi-mutarium>.



Figure 9. Unger, K., Kaisinger, J., *Fungi-Mutarium*, 2014, Utrecht University, Netherlands, <http://www.livinstudio.com/fungi-mutarium/>.

This contextual review has widened my understanding of the value of using an interdisciplinary research approach, applying theoretical environmental paradigms, current industry status and artistic practice to drive hope and innovation. The theoretical insights of Donna Haraway and Anna Tsing guide the study, emphasizing the interconnectedness of nature and human systems. Biomimicry serves as a key methodological tool, aligning with Haraway's and Tsing's perspectives to offer innovative strategies for addressing environmental challenges through nature-inspired design and material innovation.

The industry reports I have read highlight the urgent need for transformative change, emphasising the need to adopt circular systems and innovative biomaterials to minimise the environmental impact. Artistic practices, exemplified by artists like Jane Scott, Neri Oxman, and Jo Burzynska, bridge the gap between industrial technology and sustainable material applications. Collaborative works explore the potential of natural systems to inspire innovative solutions. Projects like the *Fungi-Mutarium* showcase promising avenues for transforming waste materials into valuable resources, highlighting nature-inspired solutions in addressing environmental challenges. In conclusion to this chapter, my own research contributes to the dialogue on sustainability and the future of material innovation in the textile industry. It underscores the importance of holistic approaches and collaborative efforts in driving forward sustainable solutions for a brighter future.

## Chapter 2: Methodological world



Figure 10. Turner, H. L., *Hyphal early growth of oyster phoenix mushroom in polyester waste fibre*, 2023, *HLJ Studio, Tāmaki Makaurau*.

## Research questions and Approach

I came into this research with the following question: “How can a practice-led design approach utilise biomimicry to reduce our textile waste resolve and to increase the circularity through alternative, biological systems of waste recycling?” Throughout the research, a further question persisted: “What does this organism aim to achieve, and how can I integrate it as an equal participant in the design process of an emergent bio-material?” While in the process of this research a third question was also kept close to mind; “What does this organism want to do and how can I allow it to play an equal part in this design process?”

The Investigation Incorporates three key approaches: Intuitive, hands-on and scientific, all underpinned by the principles of *Symbiotic Design Practice* and Donna Haraway's notion of *Sympoiesis*, or making-with.<sup>29</sup> By melding these methods, a conceptual framework called “Prealm” emerges—an epistemological paradigm that leverages, reflects, and re-evaluates knowledge. This framework fosters collaboration with organisms and supports a non-extractive approach.

The research adopts a biological lens, intergrating Speculative Design to complement scientific analysis. Intuitive experimentation aligns with a hands-on maker background, yielding novel findings absent in existing literature.<sup>30</sup> While navigating Biomimicry cautiously, the study prioritises designing within nature, mindful of potential extractive tendencies. Indigenous wisdom, coupled with insights from scholars like Linda Tuhiwai Smith, Robin Wall Kimmerer and Donna Haraway, informs the desired reorientation, fostering hope and transcending limitations.<sup>31</sup>

Observing mycelium growth holistically and empirically, quantitative methods track responses to different textiles and environments, aided by photographic and visual analyses. This approach acknowledges the living nature of the organism, prompting adjustments in expectations and envisioning a recalibrated future.

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<sup>29</sup> David Sanchez Ruano, “Symbiotic Design Practice: Designing with-in Nature,.” (X thesis, University of Dundee, 2016); Haraway, *Staying with the Trouble*.

<sup>30</sup> Anthony Dunne and Fiona Raby, *Speculative Everything* (Cambridge: MIT Press, 2013). Claudia Pahl-Wostl, “A Methodological Framework for Empirical Analysis,.” in *Water Governance in the Face of Global Change* (Cham: Springer International Publishing, 2015)..

<sup>31</sup> Linda Tuhiwai Smith, *Decolonizing Methodologies* (London, New York: Zed Books, 2012),. Page 44; Robin Wall Kimmerer, *Braiding Sweetgrass: Indigenous Wisdom, Scientific Knowledge and the Teachings of Plants* (London: Penguin Books, 2020); Haraway, *Staying with the Trouble*.

## Method to this research

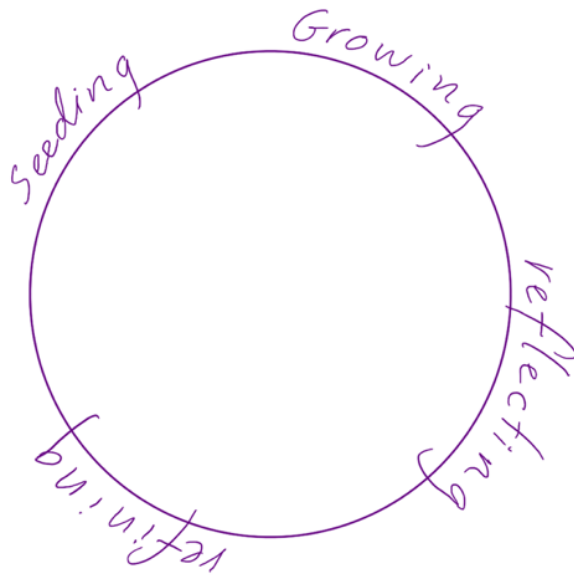


Figure 11. Turner, H. L., *Process diagram seeding, growing, reflecting, refining*, 2023, HLJ Studio, Tāmaki Makaurau.

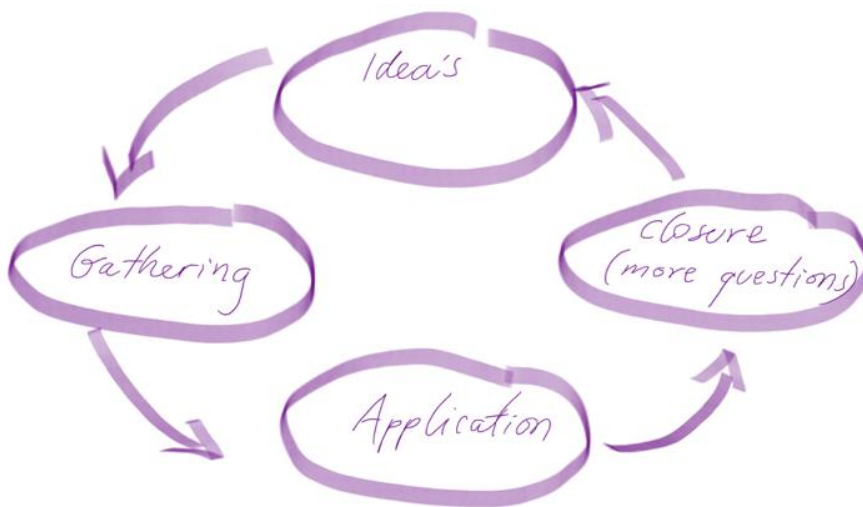


Figure 12. Turner, H. L., *Process diagram Ideas, gathering, application, closure (more questions)*, 2023 HLJ Studio, Tāmaki Makaurau.

## Process and research design

This project has involved key evolutions to develop and build upon knowledge. Self-reflective diagrams shown in figures; 11 & 12 chart the way that the practice has been carried out. The design of this is in circle form showing that the thought does not have a linear or ending result. The practice embodies the cyclical importance of rotating phases, each enriching the research, creating diversity and regeneration. I believe there is an overlap in the keywords used in each of these diagrammatic phases; *seeding/ideation, growing/gathering, reflection/application, refining/'closure' more questions.*

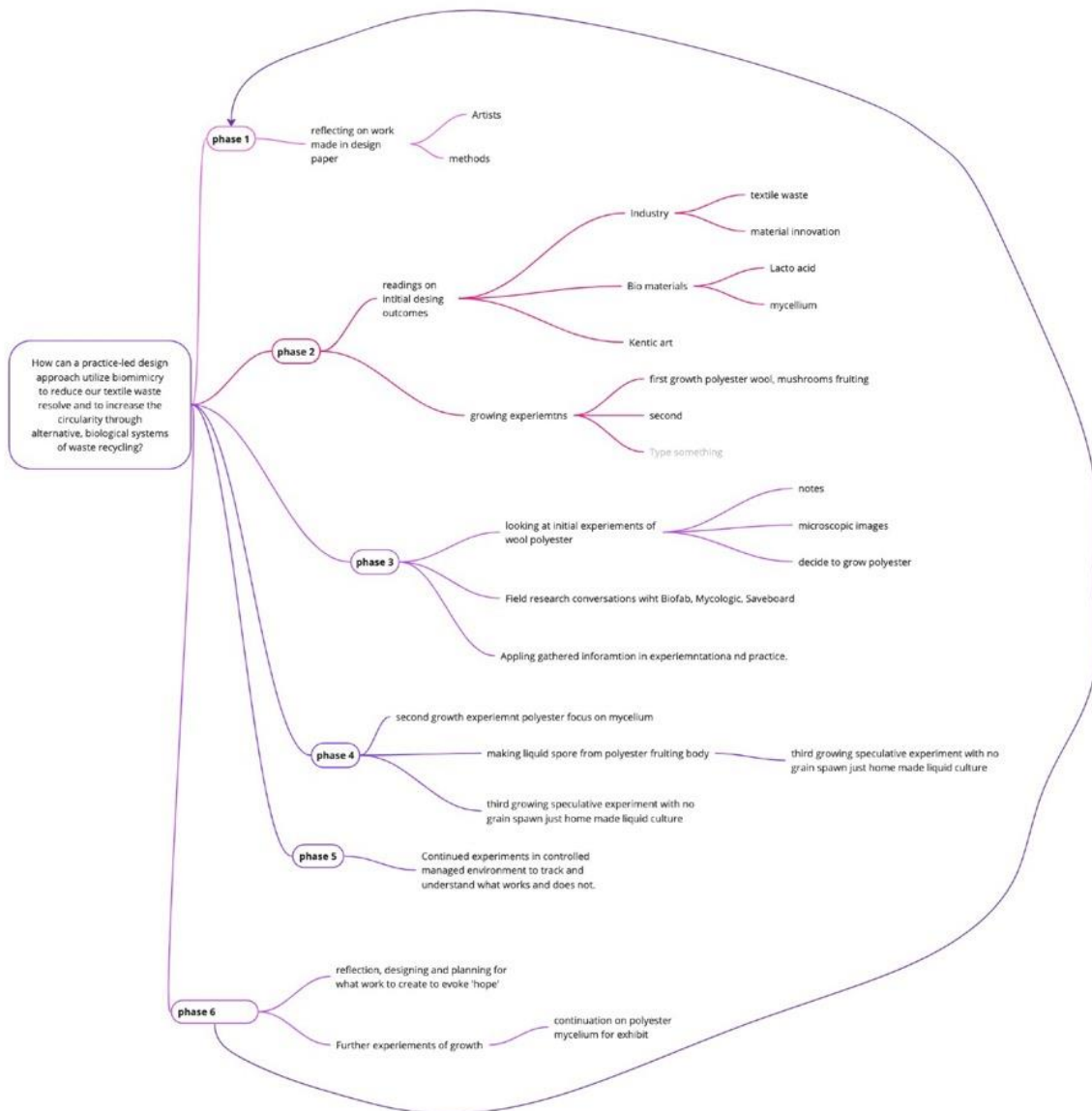


Figure 13. Turner, H. L., 6 phases, process of research, 2023, HLJ Studio, Tāmaki Makaurau.

## Phases of research

The experimental development process was broken into six phases, with numbers in a downward or evolving motion. Each number represents a tangible path to comprehend. Phase 6 reconnects to phase 1, indicating that this process needs to refer and retrack the steps to continue to understand the research findings. This cyclical process is a considerate way to gain and continue to build on new knowledge.

## Symbiotic Design, *Sympoiesis* - making-with

The *Symbiotic Design* methodology developed by David Sánchez-Ruano explores the theory of *biomimicry*, *biophilia* and *resilience* in the process of *designing within-nature*, to arrive at 4 key points in *Symbiotic Design* decision making: *science*, *ecological thinking*, *arts and design thinking*.<sup>32</sup> *Sympoiesis*, Haraway's poetic word for making-with other species and entities, identifies the importance of acknowledging that we are not making alone. She challenges the havoc created in the era of the Anthropocene, including humans dominant influence on climate and the environment, claiming instead that we must value our necessary collective effort to make-with the more-than-human entities. This theoretical discussion from *Staying With The Trouble* combines aptly with the *Symbiotic Design* framework to value and consider the living organism being researched within. This allows for sustaining and ethical foundations to build upon.

The concept of making-with is connected to my belief system that everything has a "soul", and aligns with the practices of *Animism*. Janine Benyus, David Sanchez-Ruano and Robin Wall Kimmerer, who have formed the basis of my methodology, speak about the importance of respect and reciprocity with nature, which may extend to Animist beliefs. Anthropologist David Abram states in his Essay *Animism, Perception, and the Earthly Craft of the Magician (2005)* that "'Animism' remains a useful term for this highly embodied, and embedded, mode of perception" that enables us to be considerate of the world around us. He adds: "the local animals, the plants, and the earthly elements around them have their own sensitivity and sentience... And hence that we must be respectful toward that world, lest we offend the very ground that supports us, the winds and waters that nourish us."<sup>33</sup>

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<sup>32</sup> Ruano, "Symbiotic Design Practice."

<sup>33</sup> David Abram, "Animism, Perception, and Earthly Craft of the Magician,." In *The Encyclopedia of Religion and Nature*, 2005,

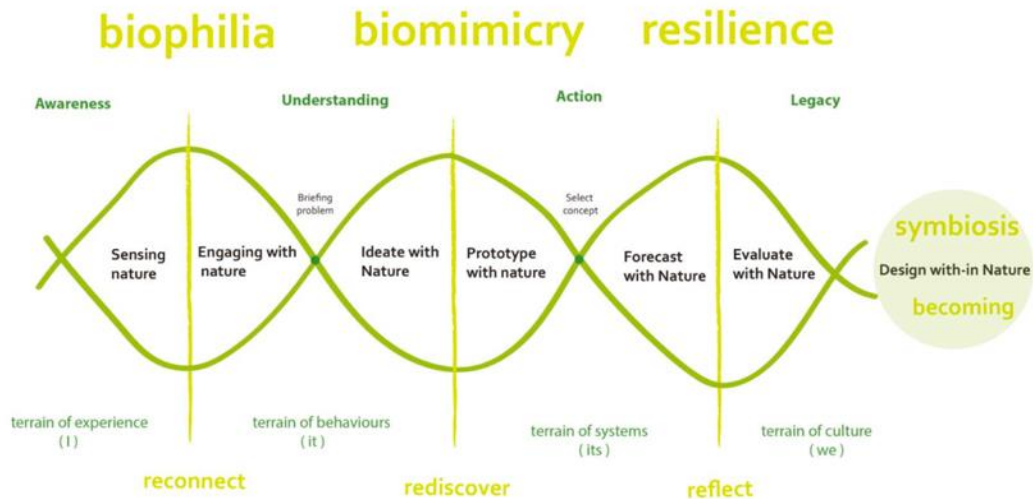


Figure 14. Ruano, D. S., *The Symbiotic Design Practice (SDP) process*, 2016, Duncan of Jordanstone College of Art and Design, University of Dundee.

## Biomimicry, Making-with, Bio-collaboration

Initial research based on biomimicry explored natural systems that consume and transform waste into new materials. However, this approach led to a sense of detachment from the organisms involved. It became evident that mimicry was not resource-efficient; instead, a shift to bio-collaboration or making-with was necessary. When employing biomimicry methods, it is essential to have a holistic approach, considering the well-being of all beings involved. For instance, Benyus highlights how mimicking a bird to design an airplane, while seemingly innovative, led to harmful outcomes.<sup>34</sup> Haraway's concept of making-with emphasises ethical considerations, particularly the dignity and welfare of organisms. During my initial experiments ethical conduct and environmental impacts were central concerns, informed by observations of mycelium behaviour. The emergence of mushrooms from the mycelium substrate suggested a positive state, guiding ethical reflections. These considerations extend to broader implications, prioritising sustainability and environmental responsibility throughout the research journey.

<sup>34</sup> Benyus, *Biomimicry*, 17



Figure 15. Turner, H. L., *Haptic approach felting textile waste fibres together for first growth experiment*, 2023, AUT, Tāmaki Makaurau.

## **Observational scientific analysis**

As this research addresses textile waste with living organisms, a biological and scientific approach has been drawn on. Due to my design, artistic, and non-science background, the depth of this research approach may be limited. However, taking a speculative and observational method of investigation opened up questions and experiments that mycologists had yet to address. Observational methods have revealed that mushrooms and mycelium thrive in waste textile fibres. This approach was consistently employed throughout the project, with image-based data documenting, qualitative progress and quantitative data collected during phase five (see Figure 13). The hands-on experimental phase included three inoculations of waste textiles with mycelium spores under identical environmental conditions, facilitating daily observations for tracking growth and comparing responses to different spawn and liquid cultures.

## Decolonising methodologies

As a Pākehā growing up in Aotearoa (New Zealand), I have witnessed negative impacts of colonised peoples and land in Aotearoa. With readings from both Robin Wall-Kimmer a Potawatomi botanist, and author of *Braiding Sweetgrass: Indigenous Wisdom, Scientific Knowledge, and the Teachings of Plants* (2013) and Linda Tuhiwai-Smith's *Decolonising Methodologies*, I have been informed about holistic practices that work with, value and consider many knowledges, beyond the linear, anthropocentric, Western lens. In the chapter *colonising knowledges* Tuhiwai Smith introduces *ways of knowing* have been formed through the development of academic disciplines and 'education of colonial elites' which has led to the 'colonisation of the mind.'<sup>35</sup>

Acknowledging I have grown up in the 'benefit' of this colonised institution, which has largely kept colonised peoples in a marginalised position with continued extractive methods in place, I have chosen to be critical of my own research practices. Tuhiwai-Smith proposes the framework for a necessarily wider, broader considered and collective research method approach. In her chapter *Research Through Empirical Eyes* she encourages contemplation to value multiple knowledges and ways of understanding. Tuhiwai-Smith argues that "the cultural archive [Western knowledge system] did not embody a unitary system of knowledge but should be conceived of multiple traditions of knowledge and ways of knowing."<sup>36</sup> Thus, as a researcher in *bio-collaboration* with the mycelium, I am interested that this project serves the wellbeing of the mycelium and all species of this planet, not merely human needs.

In this research I take into consideration some valuable questions from Tuhiwai Smith's introduction, citing Goldberg. Indigenous activists ask every researcher to consider the following questions; Who's interest does this serve? Who's research is it? Who owns it? Who will benefit from it? Who has designed its questions and framed its scope? Who will carry it out? Who will write it up? How will its results be disseminated?<sup>37</sup>

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<sup>35</sup> Smith, *Decolonizing Methodologies*, 62

<sup>36</sup> Smith, 45

<sup>37</sup> Smith, 10

## Imagining otherwise through spatial installation

In a world where multiple species, both human and nonhuman, collaborate to create spaces celebrating non-extractive methods of production, reimagining plays a crucial role in my research practice. The dream of incorporating an organism's digestion to address the issue of textile waste evolved into a collaborative effort with mycelium. The speculative structure (see Chapter 4) for hosting the novel material of 'digested' polyester textile waste fibres, is a public installation. Through an installation designed to engage the public and inspire further exploration, the *Pavilion of Hope* strives to cultivate this utopian ideal of inter-species collaboration. As Dunne and Raby eloquently express in *Speculative Everything*: "speculating is based on imagination, the ability to imagine other worlds and alternatives".<sup>38</sup> This underscores the importance of reimagining hopeful futures, for which I have chosen installation and innovative materials as a method to communicate this speculative future.



Figure 16. Turner, H. L., *Oyster phoenix fruiting in textile waste*, 2023, HLJ Studio, Tāmaki Makaurau.

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<sup>38</sup> Dunne and Raby, *Speculative Everything*, 70.



Figure 17. Turner, H. L., *Phoenix oyster mycelium and mushroom fruiting in textile waste*, 2023, HLJ Studio Tāmaki Makaurau.

## Practical methods of research gathering

## Photographic visual analysis

Utilising the method of photographic visual analysis in this research has led to documented evidence of the key phases in the response and growth of the mycelium in the textile waste substrates in each environment. This is a way of gathering data as each photograph has a date when taken and the location and environment are noted. Applying this method has supported the research design of this study and provided helpful information to reference back to key stages of growth. The photographic documentation allows for an overall visual representation of the changes over the period of growth without the need to do sketches or descriptive note-taking. The images concisely represent the evolution of the mycelium digestion over many experiments.

## Microscopic documentation

Further photographic visual analysis was applied with Scanning Electron Microscopic (SEM). The SEM is a microscope that collects images by scanning the surface of the sample using electronic beams.<sup>39</sup> This means if the sample is not conductive it requires being coated in a conductive surface. The SEM at AUT is operated by Yuan Tao who advised how to collect and prepare the samples.<sup>40</sup> The process of harvesting the samples included taking samples at key times on the growth and putting them into ethanol to dehydrate the sample.

The collection of samples was taken with sterilised tweezers of around a 5mm sample amount. The samples were placed directly into ethanol liquid sample tubes and dated. Once there was a set of collected samples for key phases of growth the samples were cut off about 2-4mm size and placed on a plate, then placed in SEM vacuum coating machine Hitachi E-1045 to coat in platinum (with a coating time of 100 seconds). Utilising this microscopic documentation allowed for confirmation of fibre types and findings related to how the mycelium responded to the fibres at different phases of the growth.

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<sup>39</sup> "Carbon & Gold Sputter Vacuum Coaters for TEM & SEM,." Agar Scientific, accessed March 15, 2024, <https://www.agarscientific.com/instrumentation/vacuum-coaters>.

<sup>40</sup> "Scanning Electron Microscope - Engineering - AUT,." Auckland University of Technology, accessed April 30, 2024, <https://www.aut.ac.nz/study/study-options/engineering-computer-and-mathematical-sciences/facilities/scanning-electron-microscope>.



Figure 18. Turner, H. L., *Samples of fibres for Scanning Electron Microscope*, 2023, AUT, Tāmaki Makaurau.

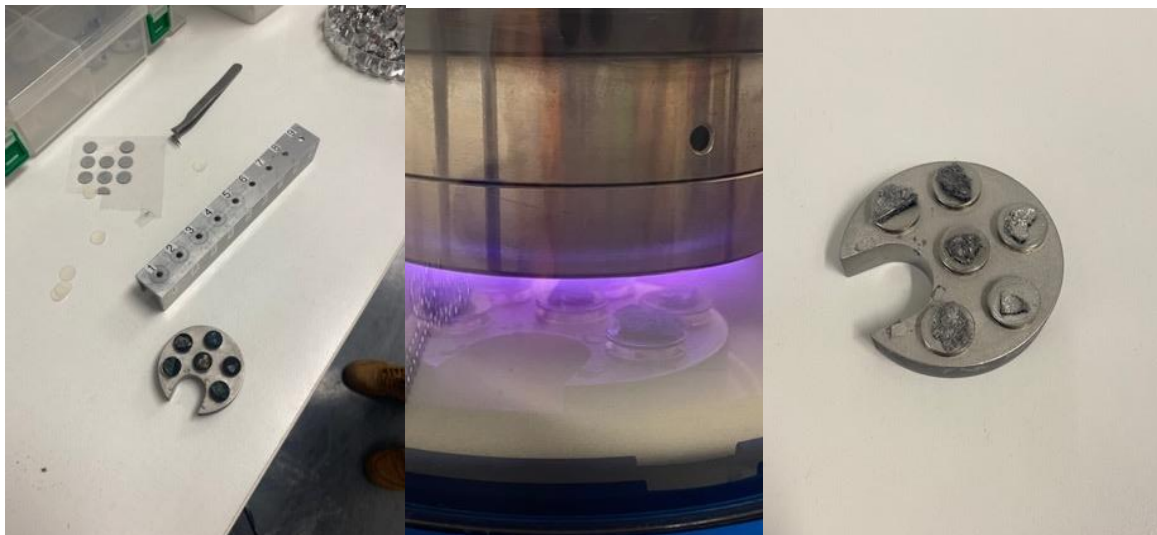


Figure 19. Turner, H. L., *Platinum coating process of mycelium and textile samples for Scanning Electron Microscope*, 2024, AUT WS Building, Tāmaki Makaurau.



Figure 20. Turner, H. L. + Toa, Y., SEM image of polyester fibre Scanning Electron Microscope, 2023 AUT WS Building, Tāmaki Makaurau.

## Field research and direct observations

In the project, an intuitive research methodology was complimented by targeted field research, direct observation, and conversations with experts to immerse myself in the environment and deepen my understanding of biomaterial design.<sup>41</sup> This method seamlessly integrated with speculative and intuitive approaches to absorb information and conduct experiments. During a visit to the *SaveBoard* factory in 2023, I witnessed innovative recycling processes, which minimized resource use while producing quality products, as discussed further in Chapter Three.<sup>42</sup> This approach, replicated in exploring textile waste, involved leveraging mycelium as a growth medium, requiring minimal energy.

Field research also included sharing ongoing experiments with Peter Thomson, a mushroom dealer, at local farmer's markets to gather feedback and advice. For instance, Thomson informed me that there was mould growing on the mushrooms. Engagement with the mycologist community, particularly Bart Acres from *Mycologic*, provided valuable suggestions and encouragement for experimentation, resembling the interconnectedness of mycelium networks.<sup>43</sup>



Figure 21. Turner, H. L., *Finished product SaveBOARD gib replacement material*, 2023, HLJ Studio, Tāmaki Makaurau.

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<sup>41</sup> Adi Bhat, "What Is Field Research: Definition, Methods, Examples and Advantages" QuestionPro (blog), September 7, 2018, <https://www.questionpro.com/blog/field-research/>.

<sup>42</sup> "Home," Save Board NZ, accessed October 13, 2022, <https://www.saveboard.nz>.

<sup>43</sup> "Mushroom Cultivation Basics," MycoLogic, accessed January 19, 2024, <https://www.mycologic.nz/mushroom-spawn>.



Figure 22. Turner, H. L., spawn pack sent including a book by Bart Acres Mycologic, 2023, HLJ Studio, Tāmaki Makaurau.



Figure 23. Turner, H. L., *Fruiting of mushroom in postconsumer wool polyester blend*, 2023, HLJ Studio, Tāmaki Makaurau.

## Chapter conclusion: Place and realm, "Prealm"

The methods and epistemologies explored in this research have deepened my questions and approach. To encapsulate the afore-mentioned methods I feel the enthusiasm to share the word *prealm*, which started in the exploration of what a heterotopic space could be in 2012. Michel Foucault explains Heterotopia as a sense of not having one linear space or order in process, which can link to a notion of decolonising methodologies and the importance of whole systems, organisms and multiple knowledges.<sup>44</sup> Haraway reframes our relationship to nature to one of kinship. She combines the words 'kin' and 'innovation' in her word 'kinnovation' and she proposes that a "kinnovator, is a person who makes family in nonconventional ways, to which I add kinnovation."<sup>45</sup>

In an essay by Michael Marder published in the Journal *More-Than-Human* he proposes *Phytocentrism* for the 'greening' of human consciousness.<sup>46</sup> I support the notion of rephrasing, renaming, or innovating with new terminology. This concept aligns with the idea of reimagining the constraints imposed by existing systems, emphasizing the vital importance of environmental harmony.

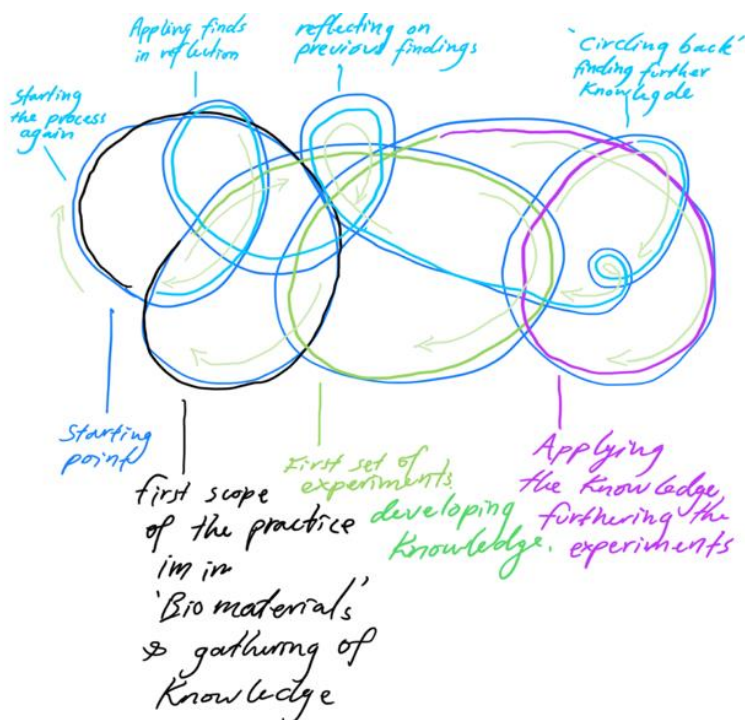


Figure 24. Turner, H. L., *Prealms, a process, Finding a place, a realm – the place to ponder, land and lift off from again*, 2024, HLJ Studio, Tāmaki Makaurau.

<sup>44</sup> Nikita A. Kharlamov, "Heterotopia, Overview." In *Encyclopedia of Critical Psychology* (New York, NY: Springer, 2014).

<sup>45</sup> Haraway, *Staying with the Trouble*, 208

<sup>46</sup> Andrés Jaque et al. (eds.), *More-than-Human* (Rotterdam: Het Nieuwe Instituut, 2020), 432.

The diagram above describes my cyclical journey, weaving through stages of exploration and reflection, continuously circling back to initiate anew. The concept of *prealm* marks the starting point, but lacks a definitive endpoint. In the diagram, I have outlined several key stages to elucidate this process: starting point, gathering knowledge, conducting initial experiments, applying gained knowledge and advancing experiments, revisiting previously discovered knowledge to uncover further insights, reflecting on prior findings, applying insights from reflection, connecting to personal or initial knowledge, and restarting the process.

Cultivating mycelium in waste textiles, despite my 'non-scientific' background, has refined this process, drawing on insights from my experience as a sourdough baker. The interconnectedness between growth, organisms, environments, and time guides this cyclical exploration, prompting ongoing development and discovery.

This research embraces a holistic approach with the integration of intuitive, hands-on scientific methodologies – and the exploration of Symbiotic Design Practice. This inclusive approach emphasises collaboration with nature, echoing concepts from thinkers like Ruano and Haraway. A deeper understanding of our ecological systems and dynamics has surfaced with the speculative epistemology and ecological sensibility of this research. By surrendering to uncertainty and wonder, the limitations of traditional approaches are dissolved, paving the way for new insights and possibilities.

Ethical and environmental considerations are embedded within the research, in particular, in terms of respecting the dignity and well-being of the organisms involved. By prioritising and practising making-with, this research aims to contribute positively to both ecological and human communities. I have acknowledged the problematic, colonial concept of "ownership" and exploitation of resources, in line with Linda Tuhiwai-Smith's *Decolonizing Methodologies*. Instead, this research aims to serve the well-being of all species and the planet, rather than solely human interests. The importance of the collaborative ownership of knowledge is recognised and acknowledging the contributions of both humans and non-human entities in the process of this research. In the next chapter the research journey reveals differing methods of experimentation and findings that further arch towards hope.

## Chapter 3: Materials Research and Experimentation

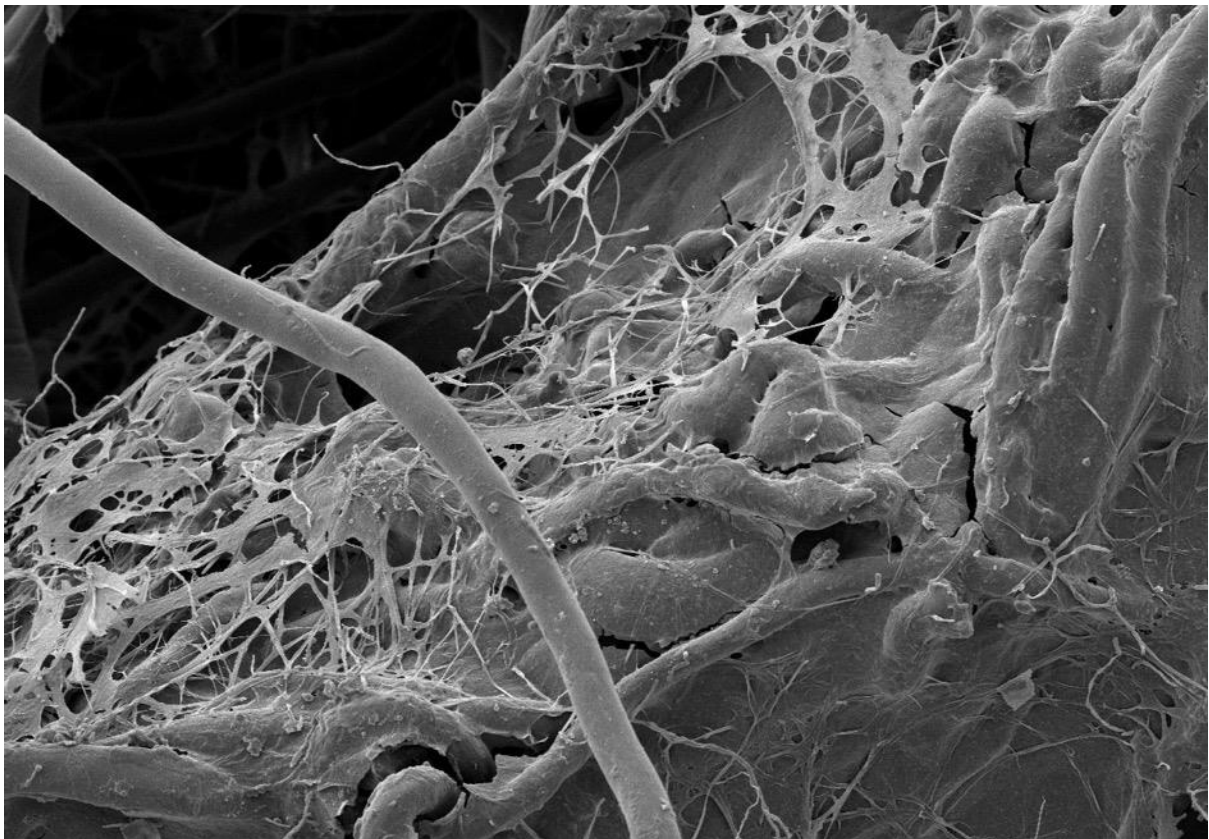


Figure 25. Turner, H. L. + Toa, Y., *SEM image of mycelium and postconsumer polyester waste* Scanning Electron Microscope, 2024, AUT WS Building, Tāmaki Makaurau.

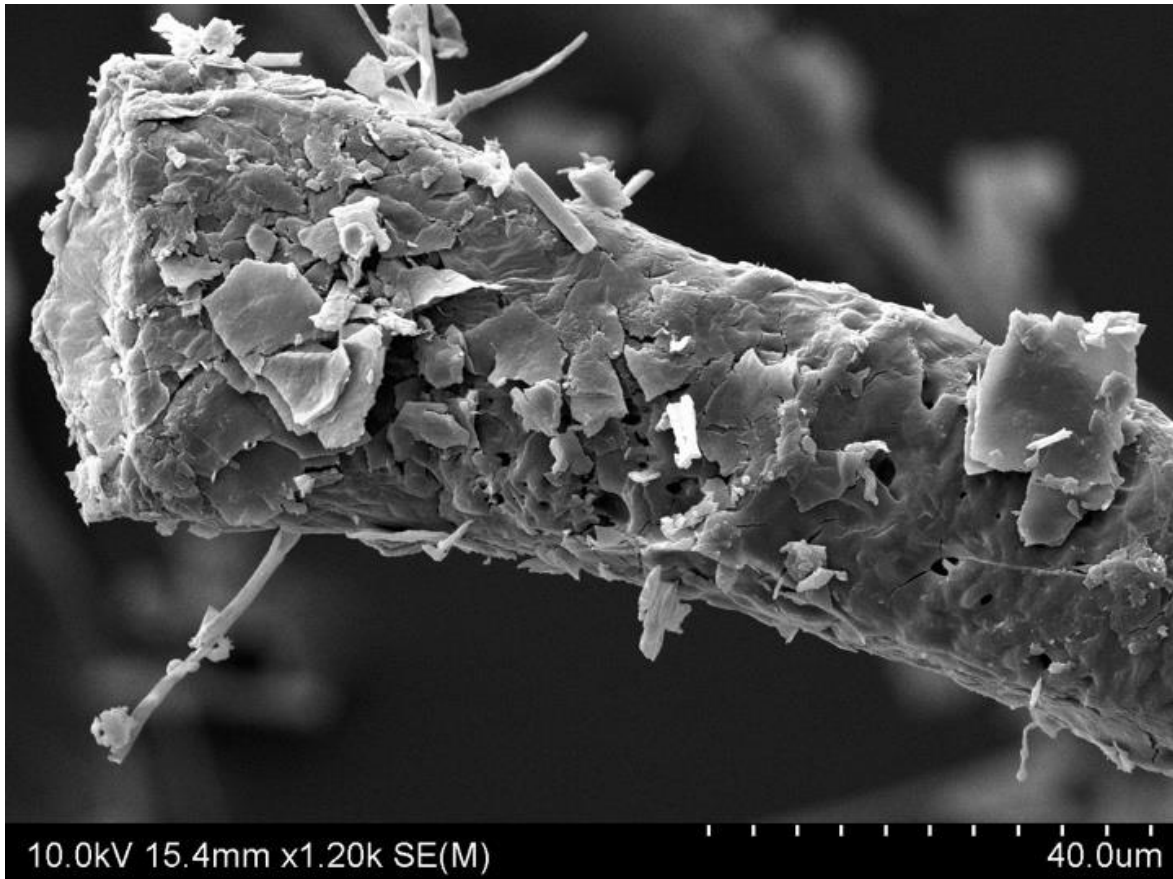


Figure 26. Turner, H. L. + Toa, Y., *SEM image of mycelium and postconsumer polyester waste* Scanning Electron Microscope, 2024, AUT WS Building, Tāmaki Makaurau.

## **Solutions to waste through imagination**

The aim of this research is to find solutions to textile waste, enabling a new perspective on and relationship with waste. I revision textile left-overs as a resource rather than waste. This research began with field trips to two recycling centres in the North Island of Aotearoa, where waste was being transformed into new material products. *Saveboard* in Hamilton works with thin plastic and Tetra Pak waste, turning them into a new gip board for building construction, while *Textile Products* in Auckland processes various textile waste fibres into carpet underlays, insulation, geotextiles and packing blankets. With the interest in working with organisms for material innovation discussions were held with *Biofab*, a New Zealand based company creating packaging with mycelium as a replacement for polystyrene.

The visits to *Saveboard* and *Textile Products* were exciting, as they showcased resources being processed and refined into high quality products that fit well into a circular system. These products can re-enter the system at the end of their life cycle. Both factories required minimal additional resources to produce their products; no washing is required, only machinery for cutting and shredding materials into small enough pieces or fibres. In the case of *Textile Products*, felting was also involved in the process.



Figure 27. Turner, H. L., *saveBoard Hamilton Factory steps from waste into 'gib board'*, 2023, HLJ Studio, Tāmaki Makaurau, <https://www.saveboard.nz/>



Figure 28. Turner, H. L., *Postconsumer textile waste process into new product by Textile Products*, 2023, HLJ Studio, Tāmaki Makaurau, <https://textile.co.nz/>

The production of *Biofab*'s mushroom packaging is an innovative and environmentally friendly product. The packaging is energy efficient as the organism grows the packaging itself, only requiring minimal machinery for stabilisation through a dehydration process that involves a machine. Currently, agricultural waste serves as the substrate for mycelium growth, to create the form of the packaging. At the end of this products life it becomes a rich feed for compost and soil which breaks down within 30 days.

The enthusiasm for my experiments was to entangle parts of both these practices to inspire a potentially new material outcome. This new approach offers not just another path directing discarded materials away from landfill, it also less processing to produce a material that can instil hope that 'waste' is an inspiring resource.

## Experimental arc for bio-material design

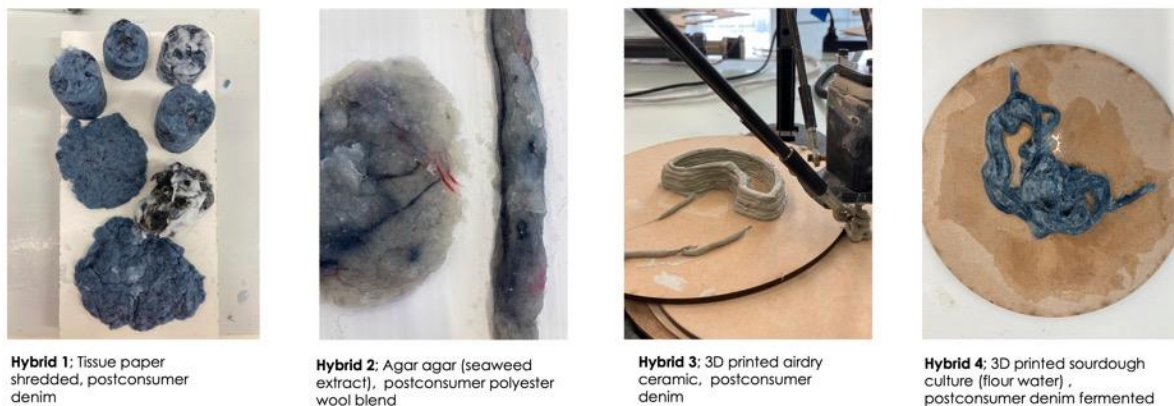


Figure 29. Turner, H. L., *Early material experimentations*, 2023, AUT Wet Lab, Tāmaki Makaurau.

## Extruding ideas

This section outlines my initial idea to grow mushrooms in textile waste. The idea was sparked from finding various publications about mushrooms claiming to degrade plastics.<sup>47,48</sup> My initial dream was to mimic an organism that could process textile waste into a refined new material. Initially proposed as a kinetic sculptural extruding process once the lactic ferment (sourdough starter culture) step had digested the fibre, mimicking the spider's digestion of proteins.<sup>49</sup> <sup>50</sup>However an issue became apparent. I came understand that the short lactic digestion process alone would not degrade the polyester fibre sufficiently to bring the 'refined fibre' closer to a cyclical concept. The *Fungi-Mutarium*, an inspirational research project mentioned in Chapter One, provided evidence of plastic being digested by the mushrooms. Therefore, mushrooms were introduced into the initial step to assist in digestion.

<sup>47</sup> Katherine Gallagher, "Plastic-Eating Mushrooms: Species, Benefits, Impact," accessed January 26, 2024, <https://www.treehugger.com/mushroom-that-eats-plastic-5121023>; Elenor Hildebrand, "50 New Plastic-Eating Mushrooms Have Been Discovered in Past Two Years" *Upworthy Science*, July 12, 2019; "Fungi Mutarium Recycles Plastic While Growing Edible Treats," *Dezeen*, December 10, 2014, <https://www.dezeen.com/2014/12/10/livin-studio-katharina-unger-fungi-mutarium-recycle-plastic-food/>; Kayla Vasarhelyi, "Plastic Eating Mushrooms,." *Environmental Center*, November 4, 2021, <https://www.colorado.edu/center/2021/11/04/plastic-eating-mushrooms>.

<sup>48</sup> Louisa Low, "Fungi Makes Meal of Hard-to-Recycle Plastic,." *The University of Sydney*, accessed March 29, 2024, <https://www.sydney.edu.au/news-opinion/news/2023/04/14/fungi-makes-meal-of-hard-to-recycle-plastic.html>.

<sup>49</sup> Elena Bartkiene, Fatih Özogul, and João Miguel Rocha Bartkiene, Özogul, and Rocha, "Bread Sourdough Lactic Acid Bacteria—Technological, Antimicrobial, Toxin-Degrading, Immune System-, and Faecal Microbiota-Modelling Biological Agents for the Preparation of Food, Nutraceuticals and Feed," *Foods* 11, no. 3 (February 3, 2022): 452; "From Old Bread to New Yarn,." *MaterialDistrict*, accessed October 13, 2022.

<https://materialdistrict.com/article/old-bread-new-yarn/>.

<sup>50</sup> *Materials*

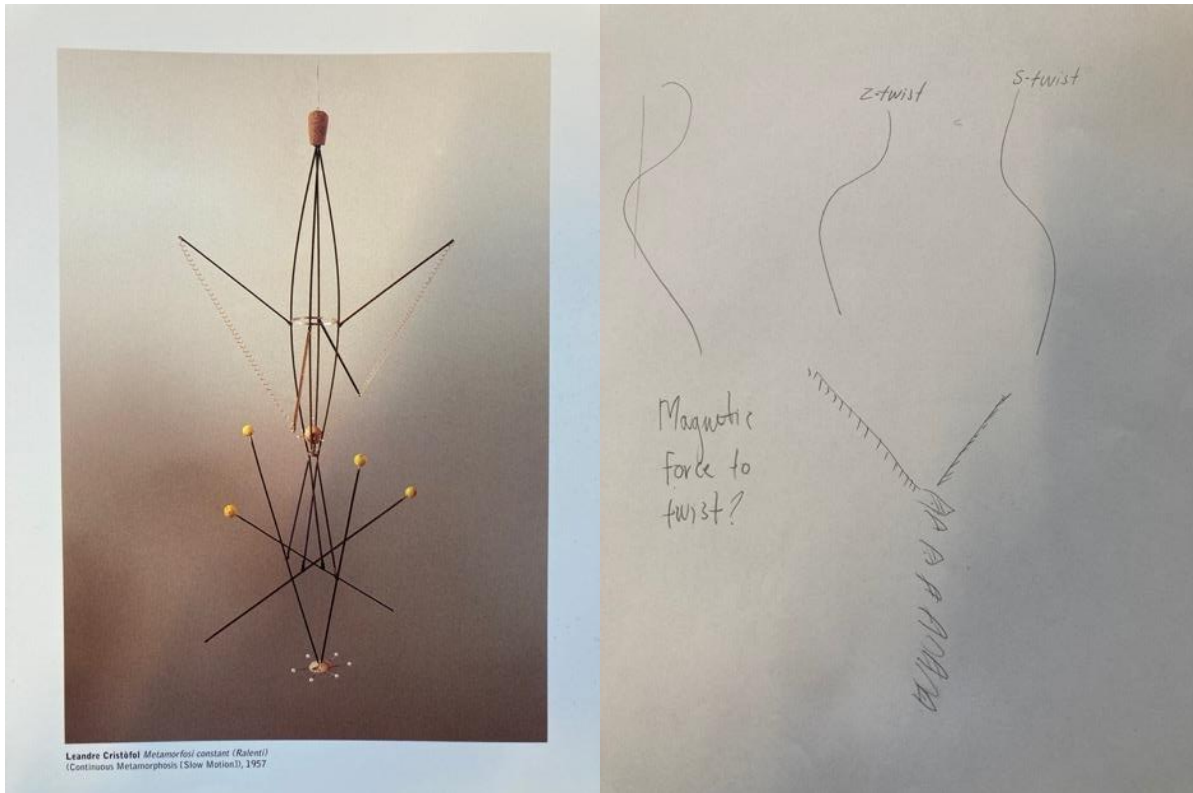


Figure 30. Leandre Cristòfol, *Continuous Metamorphosis (Slow Motion)*, 1957, kinetic artwork, Spain. Turner, H. L. *Sketch of concept*, 2023, artist's notebook, Tāmaki Makaurau.

I wondered if the next step with the mushrooms in the cycle could be to breakdown the waste to prepare it for the lactic ferment process; would this then break it down and digest it to a liquid paste, for extrusion into a new material? Relevant reading suggested that the oyster mushroom is a species that can digest plastics.<sup>51</sup> Native phoenix oyster spawn grain was purchased from *Mycologic* for the first novel experiment.<sup>52</sup> After inoculating the textile waste, a blend of polyester and wool, with grain spawn, mushrooms grew after two weeks.

<sup>51</sup> Hildebrand, "50 New Plastic-Eating Mushrooms"; Gallagher, "Plastic-Eating Mushrooms."

<sup>52</sup> "Mushroom Cultivation Basics," *Mycologic*.



Figure 31. Turner, H. L., 6th August 2023; day 1: 20% inoculated barley spawn of oyster mushroom to 80% polyester wool mix The fibre was soaked in water to begin with, to hold moisture., HLJ Studio, Tāmaki Makaurau.

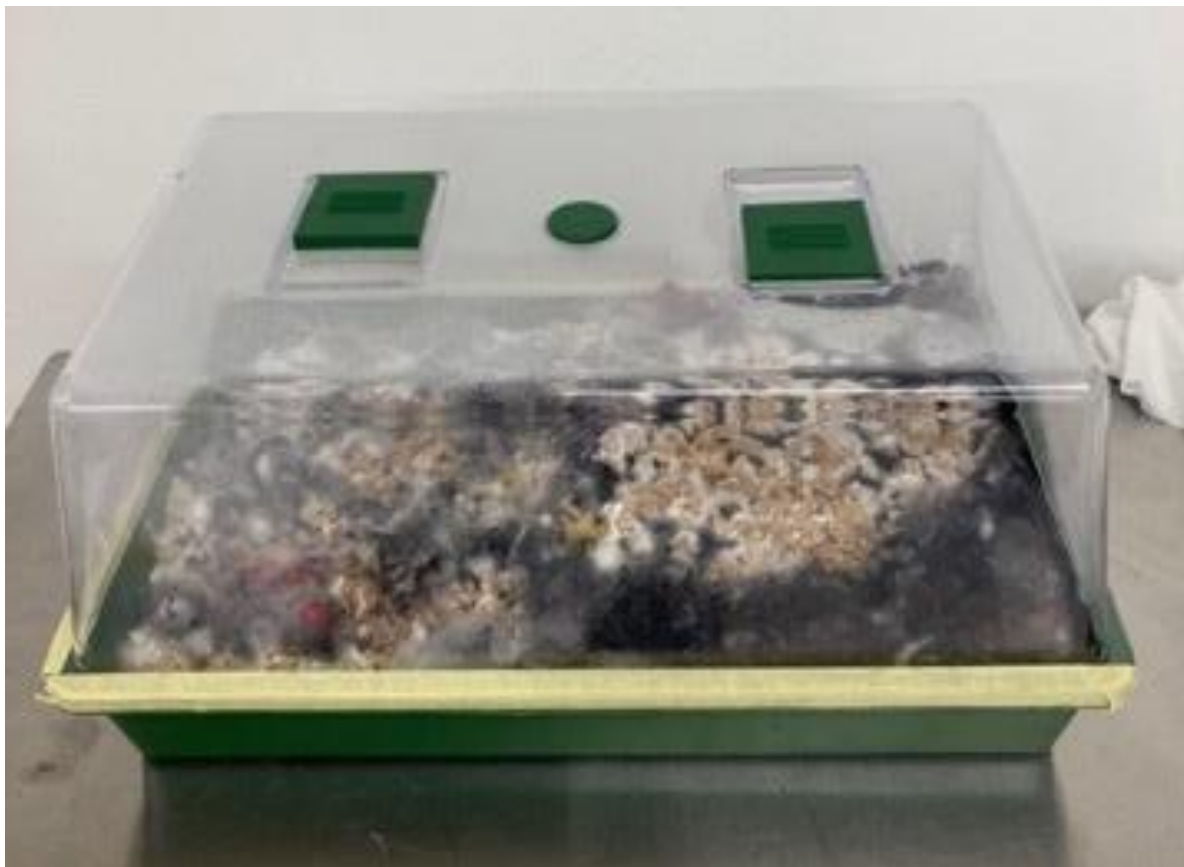


Figure 32. Turner, H. L., 5th August 2023; 9 days later: 20% barley spawn of oyster mushroom to 80% polyester wool mix began to showing strong growth of mycelium, HLJ Studio, Tāmaki Makaurau.



Figure 33. Turner, H. L. 5th September 2023; 20 days later: 20% barley spawn of oyster mushroom to 80% polyester wool mix began to showing the first fruiting of the oyster phoenix mushroom in waste fibres. HLJ Studio, Tāmaki Makaurau.

The outcome of this experiment prompted curiosity about how the mycelium processed the fibre. Further investigation of densifying the mycelium network became an interest. My research on how to cultivate mushrooms, including *Mycologic's* grow guide and discussions with James Ferrier from *Biofab*, provided an understanding about how to get mycelium growing without the fruiting of the mushroom.<sup>53</sup> Two further questions arose from this initial experimentation: Is this process changing or degrading the polyester fibre? And, could I grow mycelium on just polyester as substrate?

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<sup>53</sup> "BioFab."; "Mushroom Cultivation Basics, | MycoLogic | New Zealand." MycoLogic.

## Observing more closely

Microscopic observation was applied by taking samples at different growth periods in the polyester-wool experiment. These samples were observed with the SEM.<sup>54</sup> Findings, as shown in the images below, suggest that the mycelium sought the polyester for nurturance before the wool. Speculation included that the anti-microbial properties of the wool deter the mycelium from initial growth?<sup>55</sup> Further speculation led to the following hope-driven question; is this fungi adaptive enough to bioremediate this environmental issue with plastics? As Professor Dee Carter (University of Sydney) mentions, there is speculation that a quota 'missing' from ocean plastic pollution could be due to marine fungi degradation.<sup>56</sup> This lead to further readings on 'Bioremediation', the ability of organisms in particular fungi, to metabolise pollutants.<sup>57</sup>

These initial images, captured in the SEM microscope, reveal the possibility that the polyester could be broken down, fragmented and degraded by the mycelium's push for growth.

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<sup>54</sup> "Scanning Electron Microscope,," Wikipedia Foundation. Last modified , March 1, 2024.

[https://en.wikipedia.org/w/index.php?title=Scanning\\_electron\\_microscope&oldid=1211265947](https://en.wikipedia.org/w/index.php?title=Scanning_electron_microscope&oldid=1211265947).

<sup>55</sup> B. Caven, B. Redl, and T. Bechtold, "An Investigation into the Possible Antibacterial Properties of Wool Fibers, ." *Textile Research Journal* 89, no. 4 (February 2019): 510–16.

<sup>56</sup> Low, "Fungi Makes Meal of Hard-to-Recycle Plastic."

<sup>57</sup> Radhika Deshmukh, Anshuman A. Khardenavis, and Hemant J. Purohit Deshmukh, Khardenavis, and Purohit, "Diverse Metabolic Capacities of Fungi for Bioremediation" *Indian Journal of Microbiology* 56, no. 3 (September 2016): 247–64; Ayodeji Amobonye et al., "The Potential of Fungi in the Bioremediation of Pharmaceutically Active Compounds,." *Frontiers in Microbiology* 14 (July 12, 2023): 1207792.

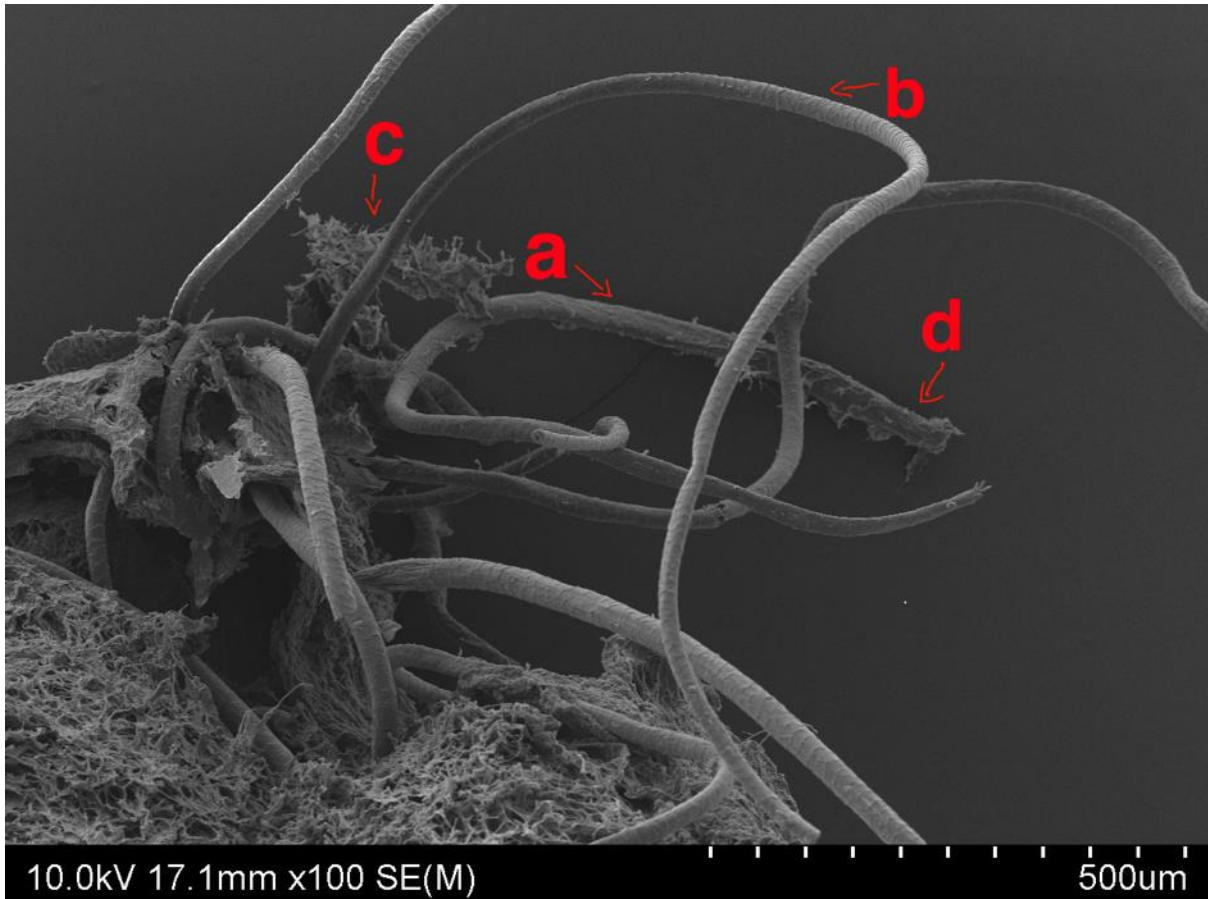


Figure 34. Turner, H. L. + Tao, Y., SEM of sample taken in September, Polyester wool substrate Scanning Electron Microscope, 2023, AUT, WS Building.

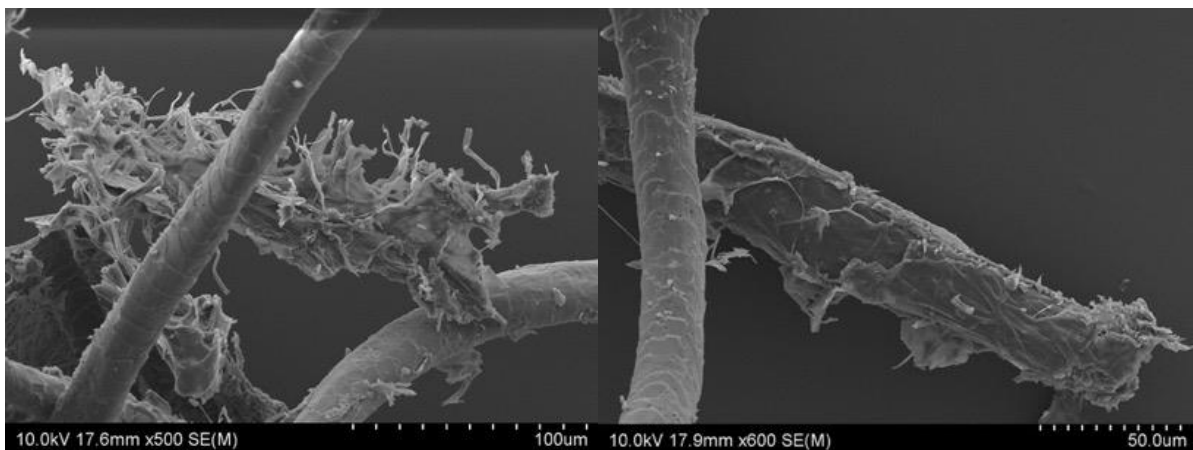
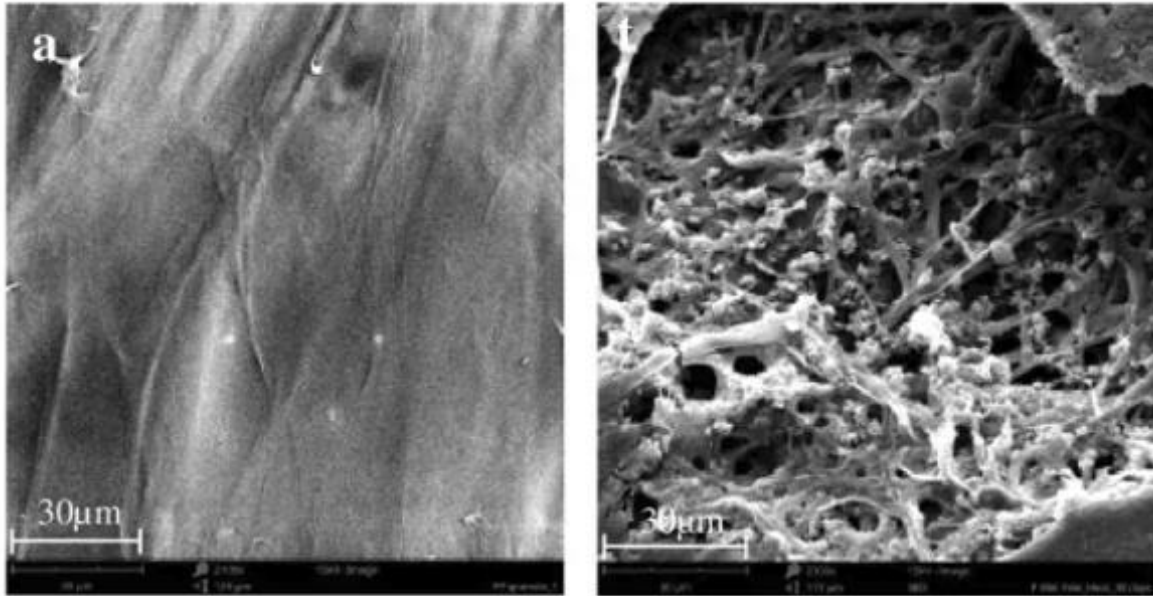


Figure 35. Turner, H. L. + Tao, Y. SEM of sample taken in September, polyester and wool substrate Scanning Electron Microscope, 2023, AUT, WS Building.

In Figure 34 above, the microscope observes the fibres of wool and polyester threads in a close-up image with mycelium growing through it. By comparing the polyester thread (a) with the wool fibre (b) we see the end of the polyester thread appears to be either breaking or being split apart by the mycelium growth (c & d). The mycelium growth on the polyester wool sample is captured in Figure 35, showing closer image captures of details c and d from Figure 34.



The plastic before (left) and after (right). Image: University of Sydney.

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Figure 36. Samat, A. F. University of Sydney's School of Chemical and Biomolecular Engineering PhD student Amira Farzana Samat show polypropylene before and after fungi has grown on it. 2023, <https://www.sydney.edu.au/news-opinion/news/2023/04/14/fungi-makes-meal-of-hard-to-recycle-plastic.html>

Figure 36 feature pictures taken by PhD student Amira Farzana Samat from University of Sydney's School of Chemical and Biomolecular Engineering. She captured images of plastic being broken-down with mycelium further supported my observational finding.<sup>58</sup>

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<sup>58</sup> Low "Fungi Makes Meal."



Figure 37. Turner, H. L., *Growth of mushroom after 3 weeks taken of the 28th November, 2023*, HLJ Studio, Tāmaki Makaurau.

Research conducted by Biolab confirmed mycelium's ability to seek more nutrients from the substrate when isolated from oxygen. This led me to conduct an experiment where the growing period of fungi without oxygen is extended, using only polyester fibre waste substrate and grain spawn. Isolating oxygen during the growing phase led to a denser mycelium network, effectively binding the textile waste into a single piece.

Reflections on the experiment with 100% polyester substrate revealed remnants of grain, prompting questions about mycelium's reliance on grain spawn and its potential to grow solely from spores on this substrate. Exploring this potential adaptability, attempts to cultivate a liquid culture from the hypha were explored. However these tests yielded no successful outcomes. Further research and adjustments to laboratory equipment and environment were made to improve future experiments in this area.



Figure 38. Turner, H. L., *Images of the textiles in liquid culture first experiment*, 2023, HLJ Studio, Tāmaki Makaurau.

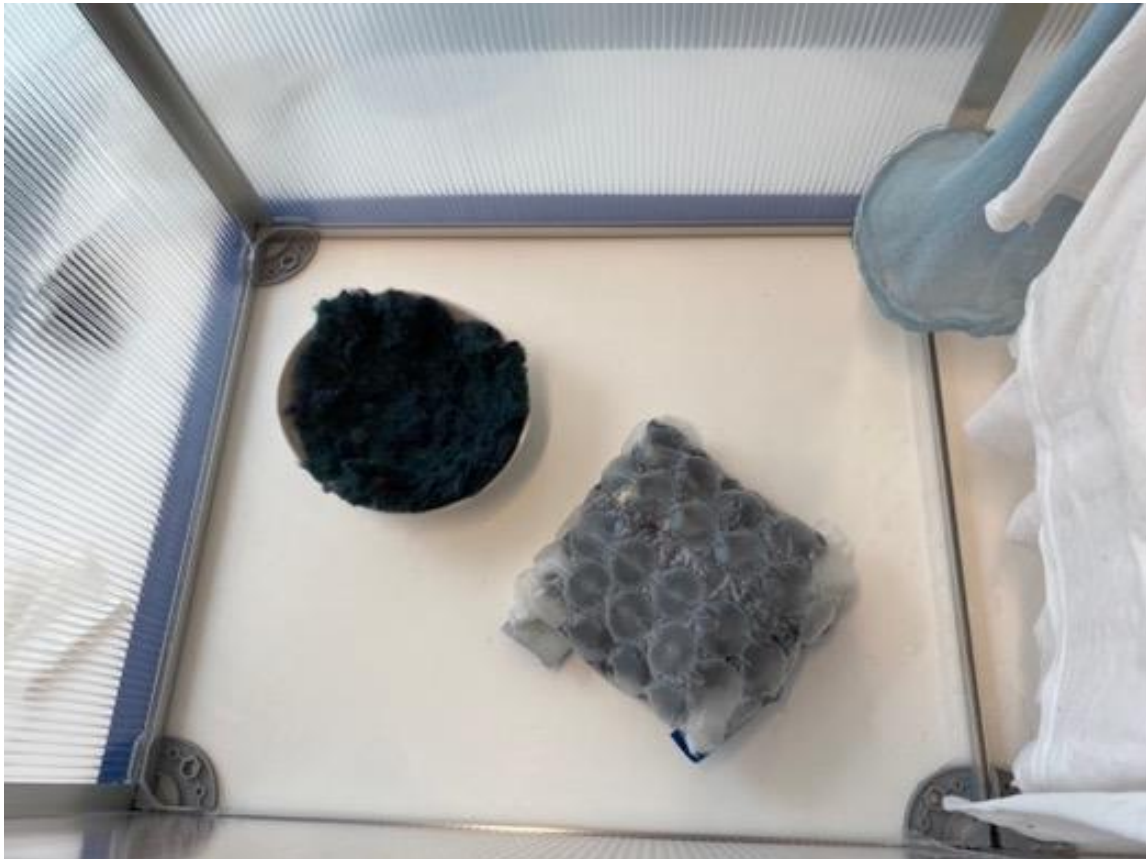


Figure 39. Turner, H. L., *Inoculation of many textile substrate forms with home-made spore liquid*, 2023, AUT WG Building, Tāmaki Makaurau.

## Findings through parallels

Due to the unsuccessful growth of the home-made liquid culture, a more controlled experimental phase was introduced. This process was documented in the charts below.

Three different methods were used for the sample period of 10 days growth, in an environment averaging at 23 degrees inside a greenhouse, in sealed individual containers.

Steps included;

- Sterilization of the growing containers with methylated spirits.
- Preparing all fabric samples with the same method, sterilized in boiling water.
- Using gloves and a mask during inoculation.
- Three different inoculation methods were carried out;
  1. Liquid culture only.
  2. Liquid culture and agar agar.
  3. Spawn grain water and flour mixture.



Figure 40. Turner, H. L., *Sample of materials prior to inoculation; PLA knit sample, cotton knit, polyester waste blend, cotton waste, wool polyester waste blend*, 2024, AUT WG Building, Tāmaki Makaurau.



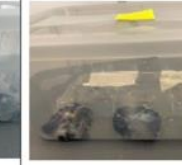
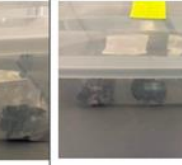
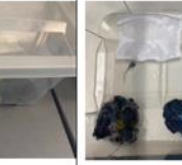
Material details	16 <sup>th</sup> Jan	18 <sup>th</sup> Jan :	19 <sup>th</sup>	22 <sup>nd</sup>	26 <sup>th</sup>
Textile waste of polyester fibers					
Textile waste of polyester and wool fibers	Cleaned in boiling water, Three drops of spore liquid	No signs of growth	No signs of growth	No signs of growth	No signs of growth
Textile waste of cotton fibers	Cleaned in boiling water, Three drops of spore liquid	No signs of growth	No signs of growth	No signs of growth	No signs of growth
Old cotton t-shirt	Cleaned in boiling water, Three drops of spore liquid	No signs of growth	No signs of growth	No signs of growth	No signs of growth
PLA knitted sample	Cleaned in boiling water, Three drops of spore liquid	No signs of growth	No signs of growth	No signs of growth	No signs of growth

Figure 41. Turner, H. L., Chart to track growth method with liquid culture in different textile waste fibres.



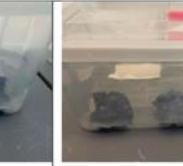



					
Textile waste of polyester fibers	Cleaned in boiling water, Agar Agar applied Three drops of spore liquid	No sign of growth	No noticeable signs of growth	No noticeable signs of growth	No noticeable signs of growth
Textile waste of polyester and wool fibers	Cleaned in boiling water, Agar Agar applied Three drops of spore liquid	No sign of growth	No noticeable signs of growth	No noticeable signs of growth	No noticeable signs of growth
Textile waste of cotton fibers	Cleaned in boiling water, Agar Agar applied Three drops of spore liquid	No sign of growth	Whispery growth of about 1.5cm tall.	Whispery growth developing large area and height	Whispery growth developing large area and height
Old cotton tshirt	Cleaned in boiling water, Agar Agar applied Three drops of spore liquid	No sign of growth	No sign of growth	Small possible bits of mold growing , likely to be a penicillin mold	Small possible bits of mold growing , likely to be a penicillin mold
PLA knitted sample	Cleaned in boiling water, Agar Agar applied Three drops of spore liquid	No sign of growth	Green mold growing.		Further mold growth

Figure 42. Turner, H. L., Chart to track growth method with liquid culture + agar agar in different textile waste fibres.

Textile waste of polyester fibers	Cleaned in boiling water, Massaged spawn grain onto the textile fiber	Signs of growth equally on each sample, some moisture. 22 degrees in the green house.	Further growth of mycelium,	Further growth of mycelium,	Further growth of mycelium, dehydration to stop growth for 2 hours at 60 degrees
Textile waste of polyester and wool fibers	Cleaned in boiling water, Massaged spawn grain onto the textile fiber	Signs of growth equally on each sample, some moisture. 22 degrees in the green house.	Further growth of mycelium,	Further growth of mycelium,	Further growth of mycelium, dehydration to stop growth for 2 hours at 60 degrees
Textile waste of cotton fibers	Cleaned in boiling water, Massaged spawn grain onto the textile fiber	Signs of growth equally on each sample, some moisture. 22 degrees in the green house.	Further growth of mycelium,	Further growth of mycelium,	Further growth of mycelium, dehydration to stop growth for 2 hours at 60 degrees
Old cotton tshirt	Cleaned in boiling water, Massaged spawn grain onto the textile fiber	Signs of growth equally on each sample, some moisture. 22 degrees in the green house.	Continued growth white and fuzzy	Continued growth white and fuzzy with some green mold	Further growth of mycelium, dehydration to stop growth for 2 hours at 60 degrees
PLA knitted sample	Cleaned in boiling water, Massaged spawn grain onto the textile fiber	Signs of growth equally on each sample, some moisture. 22 degrees in the green house.	Small green mold spot of growth.		Large amounts of green mold, dehydration to stop growth for 2 hours at 60 degrees

Figure 43. Turner, H. L., Chart to track growth method with grain spawn water and flour mixture in different textile waste fibres.

The results of these experiments indicated that only one method was suitable for encouraging the mycelium to digest the fibres, while the other two required further testing. The liquid culture experiment revealed insufficient nutrients for mycelium to develop visible signs of growth from spore liquid culture and fabric substrate. The agar agar experiment also showed inadequate conditions for growth within the given timeframe. However, samples with grain spawn successfully grew mycelium, transforming textile waste into a new material suitable for design and development for my *Pavilion of Hope* installation. Further speculative experiments explored various shapes, composites, and environments, generating unique ideas for inspiration and design considerations.



*Figure 44. Turner, H. L., Mushrooms fruiting with agar agar plate, polyester waste fibre mycelium inoculated with spawn grain, 2024, AUT, WG Building, Tāmaki Makaurau.*



Figure 45. Turner, H. L., Polyester waste fibre mycelium inoculated with spawn grain, 2024, AUT, WG Building, Tāmaki Makaurau.



Figure 46. Turner, H. L., Mattress waste with hay and mycelium, 2024, AUT, WG Building, Tāmaki Makaurau.



Figure 47. Turner, H. L., *Mycelium growing over cotton knitted structure*, 2024 AUT, WG Building, Tāmaki Makaurau.

This chapter has described the material research and waste transformation experiments, that foster a shift from viewing waste as a liability to an asset. Firsthand experiences with *Biofab*, *Saveboard*, and *Textile Products* provided inspiration and practical insights. Experimentation with mycelium and mushroom cultivation in textile waste sparked curiosity, leading to a shift towards exploring bioremediation with fungi. Parallel experiments deepened my understanding of mycelium growth dynamics. Integrating scientific inquiry with design thinking has sparked environmentally focused design solutions, with implications for waste management strategies and sustainable systems. These findings hint at the vast potential of organisms to process waste textiles, paving the way for future collaborations and material innovations. Support from mycologists and innovative companies underscore the value of interdisciplinary collaboration in driving meaningful progress and fostering optimism for the future.



Figure 48. Turner, H. L., *Dancing mushrooms in textile waste*, 2024, HLJ Studio, Tāmaki Makaurau.

## Chapter 4: Speculative pavilion



Figure 49. Turner, H. L., *Hypha and mycelium in textile waste*, 2023, HLJ Studio, Tāmaki Makaurau.

The circularity of ideation in my working process, the rotation of knowledge from both organisms, and my reading of authors including Haraway and Janine Benyus led to the semi-circular form of the 'Pavilion of Hope' to host the final stages of my research. I felt that the arch is an appropriate symbol to mark my findings; the open form invites entry into a future of hope, and foregrounds my collaboration with post-consumer textiles and mycelium, along with other living organisms.

The pavilion embodies hope through a unique collaboration between post-consumer textiles and mycelium, resulting in a new material formed through degradation and binding. The choice of an archway symbolises shelter and explores four key concepts:

- *Decentring the human*: The grown material arches beyond our human scale with the thriving organisms.
- *Bio-collaboration*: This structure represents a portal into a future where organisms and humans work together to create collaborative outcomes in harmony.
- *Industry application*: The constructed structure features a material concept that can be considered for future built environments.
- *Resource recycling*: Textile waste is utilised in the pavilion as an abundant resource. The six kilogrammes of fibres per textile brick, each forming a part of the arch form, is an impactful scale of waste that is transitioned away from becoming landfill.

Historically archways have been used as symbolic gestures and markers of a new direction of humanity, such as the *Arc de Triomphe*, Paris (1836) or the *Brandenburg Gate*, Berlin (1791), which became a symbol of unity in 1989 when the Berlin Wall came down.<sup>59</sup> Onehunga's Jellicoe Park in Tāmaki Makaurau, made an *Arch of Remembrance* (1929) for the soldiers from World War One. Built from volcanic scoria rock, it has become a symbiotic living arch, growing ferns over and through it.<sup>60</sup> These arches combine the idea of the portal, as entrance ways into parks and gardens, in addition, arches are often cultural icon as all the examples I have shown which concern historical narratives. With the *Pavilion of Hope* arch I want to convey the unity of humans and organisms stepping into an era of *bio-collaboration* and animism.

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<sup>59</sup> Lorraine Murray, "Arc de Triomphe | History, Location, & Facts | Britannica.," Encyclopedia Britannica, last modified March 14, 2024; "Brandenburg Gate", berlin.de, accessed April 26, 2024. <https://www.berlin.de/en/attractions-and-sights/3560266-3104052-brandenburg-gate.en.html>; The Editors of Encyclopedia Britannica, "Brandenburg Gate, | Iconic Monument, Berlin, Germany | Britannica." Encyclopedia Britannica, April 5, 2024, <https://www.britannica.com/topic/Brandenburg-Gate>.

<sup>60</sup> "Onehunga War Memorial.," New Zealand History, accessed May 5, 2024, <https://nzhistory.govt.nz/media/photo/onehunga-war-memorial>.

The reimagining of materials, design and architecture in the *Pavilion of Hope* has precedents in the speculative installations of designer Dr Neri Oxman, designer Dr Jane Scott and artist Dr Jo Burzynska. As discussed in Chapter Two, Neri Oxman and her team at the Massachusetts Institute of Technology (MIT), created the *Silk Pavilion* (2013), a work that collaborated with live silkworms.<sup>61</sup> Similarly, Dr Jane Scott lead a research project with the *Living textiles* group at Newcastle University with a knitted structure acting as a scaffold for mycelium to grow inside. The work *Bioknit* (2022) conceptually and technically challenges traditional industry methods. Scott states “our aim is to fundamentally change both how and what we ‘build’”.<sup>62</sup>

Jo Burzynska's *Hyphal Space* exhibition (2023) in Aotearoa (New Zealand) evokes resilience through symbiotic human-fungi relationships amid unfolding environmental crises. The meditation structure, inspired by the native basket fungus *Tūtaewhatitiri*, symbolises sanctuary and draws on the knowledge that fungus often grows after thunderstorms, offering a utopian vision of creating refuge as climate patterns become more turbulent.<sup>63</sup>

My pavilion archway is designed to cultivate a sense of hope and reciprocity to nature during the current era of the Anthropocene, the era of the human dominance over the environment. Conceptually, I propose this can be achieved by communicating the possibility for union with organisms that have the power to bioremediate.<sup>64</sup> This advances the ways we can grow materials which are less extractive due to being grown from protein and sugar rather than produced with machines that require oil or electricity.

In the case of my pavilion, the Native Phoenix Oyster mycelium (*Pleurotus pulmonarius*) breaks down and binds the polyester waste fibres, predominantly from work wear uniforms, into forms to build with.

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<sup>61</sup> “Silk Pavilion I.” The team researched the way the worms usually knitted in 3 dimensional form and designed a framework to collaboratively allow them to knit in 2 dimensional form. The Industry method for silk extraction is done by boiling and killing the worm in the process, while this living canopy evokes a celebration and graspable method of making-with living organisms.

<sup>62</sup> Romy Kaiser et al., “BioKnit: Development of Mycelium Paste for Use with Permanent Textile Formwork.” *Frontiers in Bioengineering and Biotechnology* 11 (July 14, 2023): 1229693; “Is Furniture Made from Fungus the Future?” ”

<sup>63</sup> “Jo Burzynska.”; “Ileodictyon Cibarium (Matakupenga, Kōpurawhetū, Tūtaewhatitiri, Whareatua).” Science Learning Hub, accessed April 26, 2024, <https://www.sciencelearn.org.nz/images/3723-ileodictyon-cibarium-te-matakupenga-te-kopurawhetu-te-tutaewhatitiri-te-whareatua>.

<sup>64</sup> Aline Ratuchne et al., “Pleurotus Ostreatus and a Novel Fungal Composite,.” *Resources, Conservation & Recycling Advances* 19 (November 2023): 200167. Bbioremediation occurs when an organism is introduced to an environment to reduce its pollution.

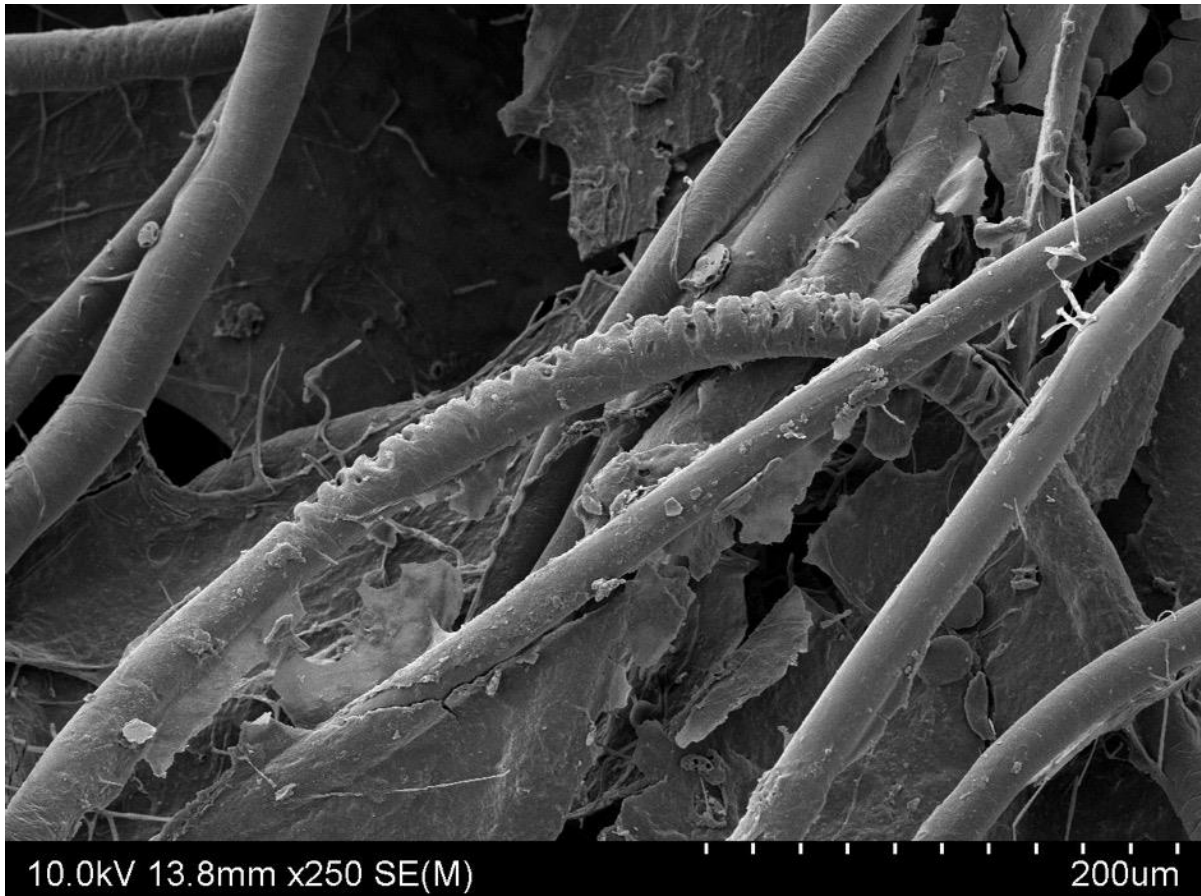


Figure 50. Turner, H. L. + Tao, Y., *Postconsumer polyester uniforms with mycelium digesting and growing through (20 days of growth)*, Scanning Electron Microscope, 2024, AUT WS Building, Tāmaki Makaurau.

The production of 1 m<sup>3</sup> of concrete it requires 2,775 MJ of energy. This energy comes mostly from oil burning, which generates CO<sub>2</sub>. 2.775 MJ of energy is produced by 0.37 barrels of oil.<sup>65</sup> My understanding from the personal experiments shown in Chapter Three is that the mycelium requires only proteins from grain and water to grow on a substrate in an environment that is kept between 20-28 degrees Celsius, which provides strong evidence that this material is already on its way to competing with extractive construction materials. This comparison is effective because while both processes require water, time, space and the transport of goods, yet the process for growing mycelium does not require a third of a barrel of oil.<sup>66</sup>

<sup>65</sup> Francesco Guidetti, "Energy Consumption in Production of Concrete,," Geoplast (blog), August 28, 2017, <https://www.geoplastglobal.com/en/blog/energy-consumption-production-of-concrete/>.

<sup>66</sup> Yangang Xing et al., "Growing and Testing Mycelium Bricks as Building Insulation Materials," IOP Conference Series: Earth and Environmental Science 121 (February 2018): 022032; Ilvy Bonnefin, "Emerging Materials," Accessed April 20, 2024. <https://www.certifiedenergy.com.au/emerging-materials/emerging-materials-mycelium-brick>; Alireza Javadian et al., "Application of Mycelium-Bound Composite Materials in Construction Industry,," SOJ Materials Science & Engineering 7, no. 2 (2020): 1-9. <https://doi.org/10.3929/ETHZ-B-000543782>; "Biocement - Biomason,," Biomason, Accessed April 20, 2024. <https://biomason.com/biocement>.

The process for making *The Pavillon of Hope* considers resource responsibility, respect, and adaptability for and with nature. The problematic waste fibres, in this case, polyester from postconsumer garments, are being placed with fungi to collaborate in a degradation and binding process which embodies this paradigm. Witnessing the interaction of mycelium and polyester waste resulting in a hybrid grown material offers an alternative path to the Anthropocene. This alternate pathway, combining 'man-made' materials and natural systems is much more suited to Haraway's concept of the *Chthulucene*, an era where we see the decentralization of humans, a time of *sympoiesis*, a making-with the community of multispecies others.<sup>67</sup>

Together we can enter through this arch of collaboration into a future of hope guided by the regenerative nature of fungi.

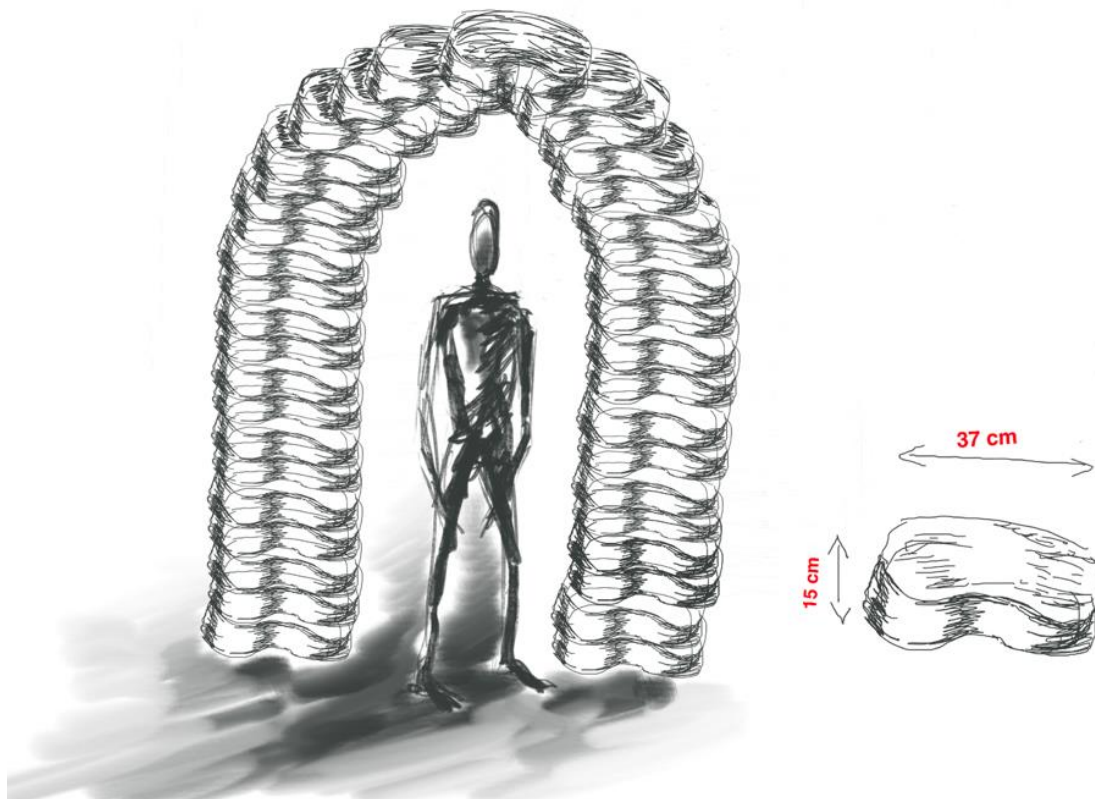


Figure 51. Turner, H. L., *Structural sketch for The Pavillon of Hope, made from textile mycelium forms stacked like brick to form an arch way, 2024.*

<sup>67</sup> Haraway, *Staying with the Trouble*.

## Chapter 5: Conclusion

### Mycelium future-scape

This chapter concludes the fruitful process that explored resolutions to textile waste employing methods of biological resource efficacy. New concepts extending beyond biomimicry were found through collaboration with organisms. Initial readings of texts by Donna Haraway, David Reano-Sánchez, Anna Tsing and Janine Benyus informed and supported the methodological framework.<sup>68</sup> The work of artists Jane Scott, Jo Bruynzaska and Neri Oxman reinforced my intent to create works that embodied hope through grown materials. This practice-led research employed both empirical and speculative experimentation methods, allowing a path to unfold, leading to possibilities that might not be explored in traditional practices.

During reflection on my research process, I established a new term: Prealm, an amalgam of Place and Realm (Prealm). This word captures my research methodological process as wandering, forward, looping back, travelling through pockets, revisiting those pockets and circling back to begin again. The process of collaboration with organisms contributes positively to both ecological and human communities endorsing a non-extractive way of producing biomaterials. The initial experiments with the successful growth of mushrooms in the textile waste created a focused direction and collaboration with mycelium. Microscopic observation of the organism's response to the polyester fibres led to a speculative conclusion: as plastics become part of our natural environment, these organisms intelligently adapt, or evolve to return pollutants into nutrition for species that otherwise could not break them down.

Further explorations and opportunities from this expanding topic of bio-collaboration are being developed. Research into fungi's bioremediation abilities and industry adapting building material practices with mycelium is accelerating. For example, the Redhouse architecture group who are applying mycelium to process the multiple abandoned homes filled with pollutants in Clevedon USA, are creating

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<sup>68</sup> Haraway; Ruano, "Symbiotic Design Practice: Designing with-in Nature."; Tsing, *The Mushroom at the End of the World*, 2021; Benyus, *Biomimicry*.

biocycler bricks, made with a *bioterrial* method - both terms coined by Redhouse Principal Chris Maurer.<sup>69</sup>



Figure 52. RedHouse Studio, *Process of biocycler bricks*, 2022, <https://www.redhousearchitecture.org/biocyclus>.

There is great potential to further examine mushroom growth on rare species, that have similar molecular structures to polyester, such as the Kanuka tree, to further inform the degradation of plastic in our local environment. I propose that any biomaterial ventures should focus on native spores, with an importance not to disrupt or harm Aotearoa's biosecurity and ecosystem.

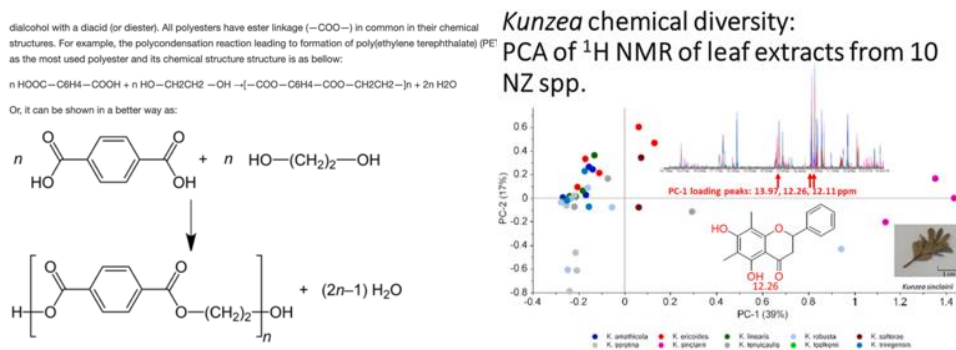


Figure 53. Screenshots, *polyester molecular structure and kanuka oil*, 2024, 10.1016/0003-2697(75)90643-0, 10.1016/j.phytochem.2022.113098.

Artistic practices drive market innovations by envisioning future possibilities and transcending limitations. Examples like *Mycotectural Alpha* (2009) and *Hy-Fi* (2014) showcase how collaborations between artists and material companies have led to

<sup>69</sup> "Biocycler," Redhouse, accessed April 24, 2024. <http://www.redhousearchitecture.org/biocyclus>; Nick Hilden, "In Cleveland, Mushrooms Digest Entire Houses" BBC, March 16, 2024. Accessed April 24, 2024. <https://www.bbc.com/future/article/20240314-fungi-can-be-used-to-clean-pollution-and-combat-climate-change>; Health Materials Lab, "Mycelium Millennium," YouTube Video, 1:14, September 7, 2022. <https://www.youtube.com/watch?v=Aj66yKohk9Q>.

established products in industry.<sup>7071</sup> The power of conceptual experimentation and evocative art installation can seed the way forward in both the textile industry and the public imagination.

The *Pavilion of Hope*, an arch grown from mycelium feeding on textile waste, embodies the aspirational vision which was found through the experimentation process. This outcome came from growing viable materials that have the ability to support the degradation of polyester, binding waste fibre into a new material. Further questions arose from this process: How could mycelium-textile waste bricks be developed as a biomaterial? Could it be a temporal material that would be used short term to eventually return to the earth, already fertilised and rich for new life to grow – rather than a pollutant and waste? The arch offers a portal to enter into a world that decentres the human. In this environmental crisis, there lies an opportunity to look to nature, actively reimagine our relationships, and envision a future of multispecies collaboration.



Figure 54. Turner, H. L., *Phoenix oyster fruiting in polyester wool fibre waste*, 2023, HLJ Studio Tāmaki Makaurau.

## POSTSCRIPT

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<sup>70</sup> Javadian et al., “Application of Mycelium-Bound Composite Materials in Construction Industry.”; Hira Sheikh et al., “Creative Futuring for More-Than-Human Worlds: Exhibitions as Sites to Ponder Environmental Governance,” *Leonardo* 56, no. 6 (December 1, 2023): 606–12. [https://doi.org/10.1162/leon\\_a\\_02431](https://doi.org/10.1162/leon_a_02431).



Figure 55. Turner, H. L., *Pavilion of Hope*, archway made from mycelium grown through polyester with textile fibres predominantly from old work uniforms, with central stabilising metal rod, 2024, Te Wai Ngutu Kākā Gallery. Tāmaki Makaurau.

## Personal reflections on The Pavilion of Hope a public exhibition

The final outcome of this research was the creation of 46 mycelium textile bricks, which were stacked into an archway named the *Pavilion of Hope* for public exhibition at Te Wai Ngutu Kākā Gallery, AUT. The journey of *making-with* mycelium and textile fibre waste informed my role as designer. During the process I was confronted with the many obstacles and expectations working in an uncontrolled lab environment.

Practically, the theoretical position of *making-with* under the constraints of time pressure to produce a 'finished installation' was a major challenge, but ultimately it strengthened my connection with mycelium, deepening the collaborative process. The greenhouse was at full capacity with the production of mycelium growing through the fibre. I felt an adverse sense of effectively 'farming' and therefore doing wrong. Regardless, when the mycelium grew in all its unique forms and the contamination from other fungi species got involved, I was again reminded of the power of nature and its natural leadership. The challenge fostered a sense of surrender and a need to revisit early experiments to understand how to work through this situation. At that point, I actively utilised and put into practice the method of *Prealms*; continuously circling back to initiate anew. I continued as a collaborator,

learning from the mycelium and rather than director and scientist fitting more into a mixed role of designer, dreamer, prealmer and artist. The process to create the brick form started with making a mycelium protein-rich mixture, and mixing this through prepared textile fibre which was placed in boxes where it grew for a couple of days. It was then transferred into an organically shaped PVC mould that had space for the mycelium to decide how it grew. After an average of 3-4 days, the result was then transferred into the kiln, 90 degrees Celcius for around 4 hours, where it transformed from a soft, moist form into a dense, strong, dry one.

The final exhibited work offered additional learnings and conclusions. An unforeseen experience was finding out how art and design audiences might feel in the presence of this biomaterial arch. The smell became a key factor in the continued storytelling nature of the work. Senses of discomfort and curiosity were evident in members of the audience. People found it somewhat confrontational that this textile was in a state of decomposition. Questions like: what is that smell? What is this? On finding out what they were looking at, people became excited by the possibility that mycelium could have the power to create a new material with our waste.

Responses to the excess of textile used to create the 46 bricks, included viewer's own concerns with the waste issues of the textile and fashion industry. A surprise outcome was learning that, given the average weight per brick was .6kg, the total arch of textile fibre amounted approximately to 31.75kg of garments. This figure is equivalent to the average amount of garment and textile waste per citizen per year in the USA.

The installation, through its raw form, smell and process of growing, presented a collaboration with multispecies that decentres human interests. Building with the unique phases of the form's growth, allowed for creativity and openness rather than conforming to a controlled, or colonising position. The *Pavilion of Hope* may be viewed as a decolonising symbol, presenting proudly as a living form, growing and challenging the expectations of a sterile synthetic gallery environment.

Envisioning future biomaterials for the world through artistic practice was an aim of this research. Encouragingly, the arch structure was strong and durable for the exhibition and also conveyed interesting audio-absorbing properties. Whilst standing inside the arch, the loud voices and chatter of the opening evening were dampened. Affirmatively, the work prompted feedback and discourse that explored questions of how the process could be utilised in various industry material applications.

The execution of an exhibition experience of the *Pavilion of Hope* reinforced my research motivations and conclusions that the work could seed further research in the development of bioremediation, the introduction of mycelium and or other protein-eating micro-organisms into textile waste and or plastic waste sites.

With optimism and gratitude, I have explored the power of mycelium and I believe in its capacity to transform how we humans interact with the natural world to restore a balance and sustainable path forward.



Figure 56. Turner, H. L., *Pavilion of Hope*, archway made from mycelium grown through polyester with textile fibres predominantly from old work uniforms, with central stabilising metal rod, 2024, Te Wai Ngutu Kākā Gallery. Tāmaki Makaurau.



Figure 57. Turner, H. L., *Pavilion of Hope*, archway made from mycelium grown through polyester with textile fibres predominantly from old work uniforms, with central stabilising metal rod, 2024, Private garden Laingholm, Tāmaki Makaurau.

## Appendix

In this appendix I share a series of images that document the process of making the mycelium textile bricks for the Pavilion of Hope archway installation, including additional microscopic images of the polyester fibre being eaten by the mycelium. Plus the final place that the sculpture may live until it returns to the earth, not as synthetic fibre but as a natural bioproduct of mycelium metabolism. Refined through its digestion.

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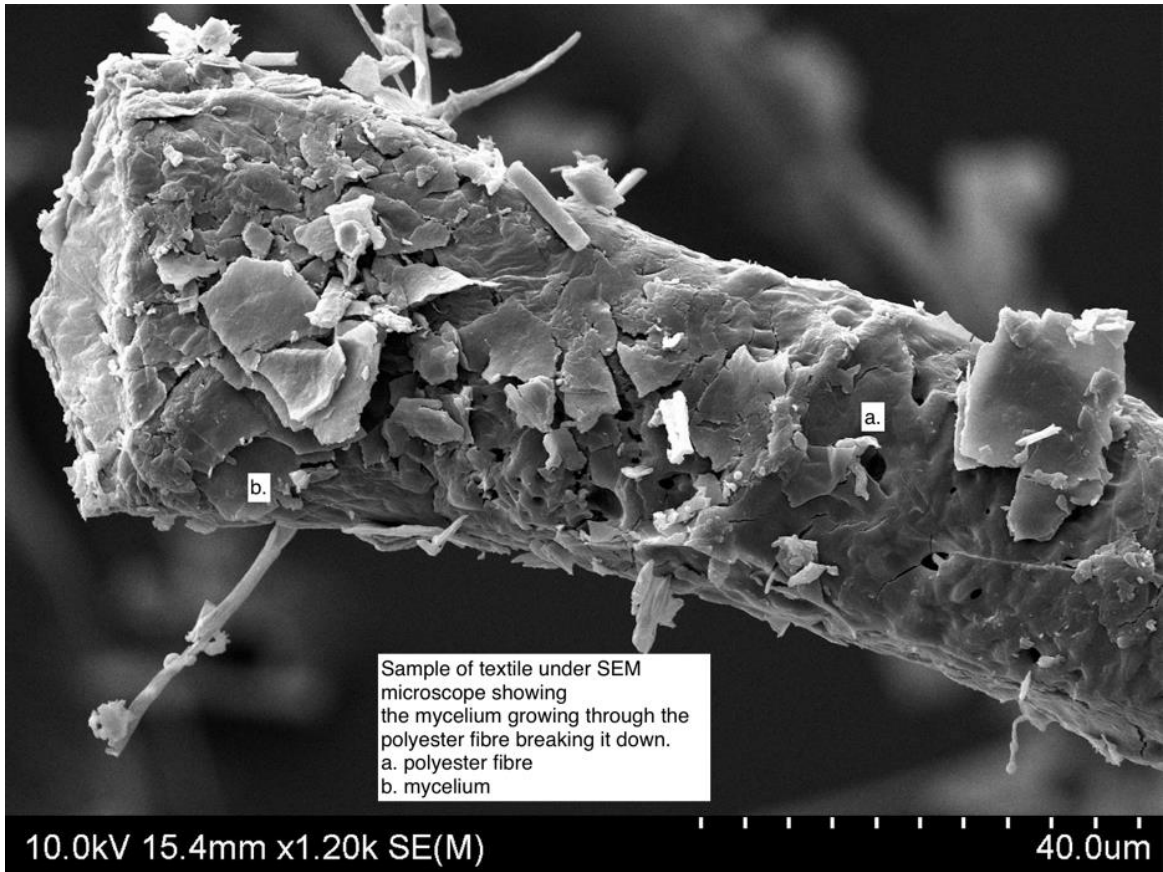
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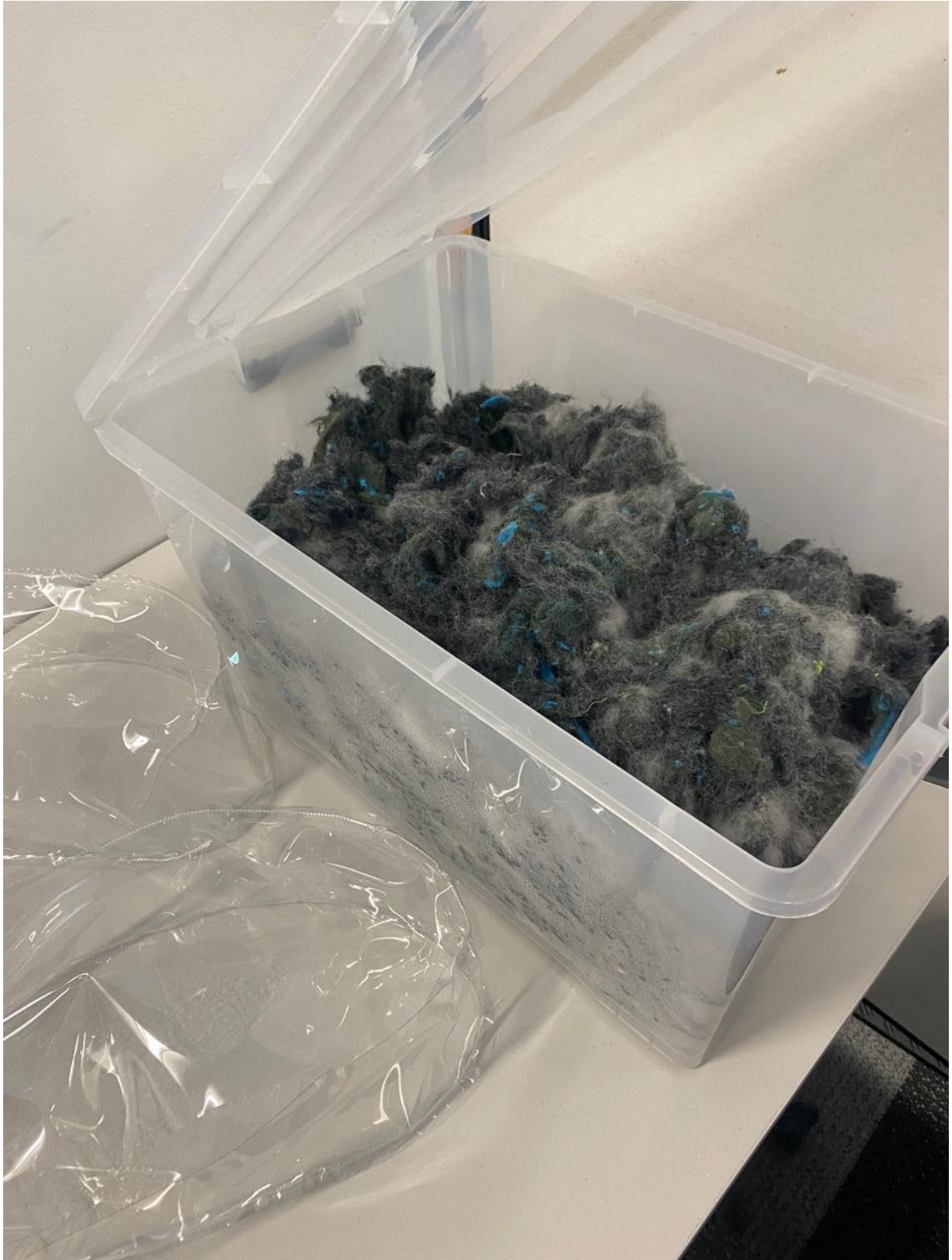
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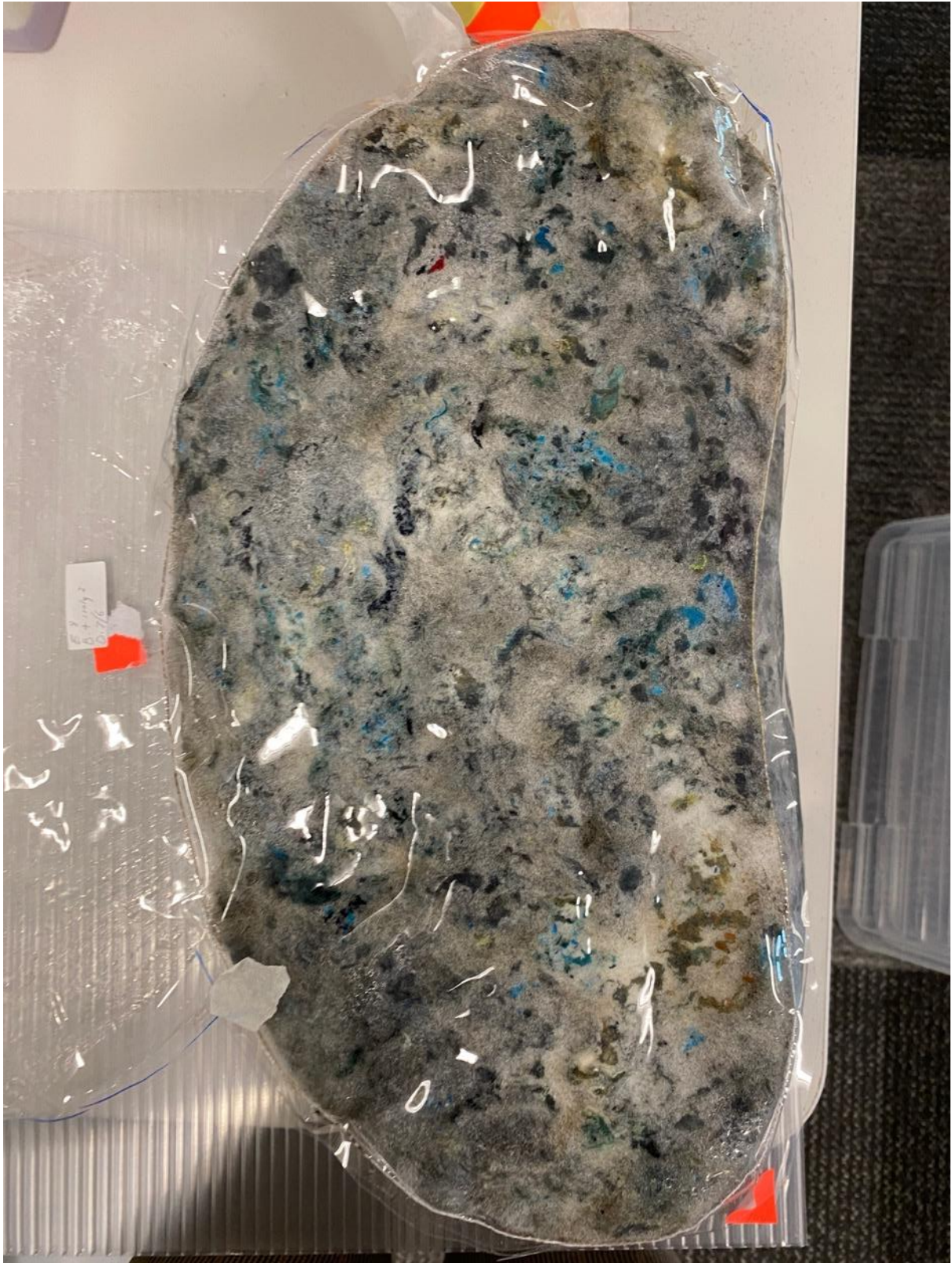
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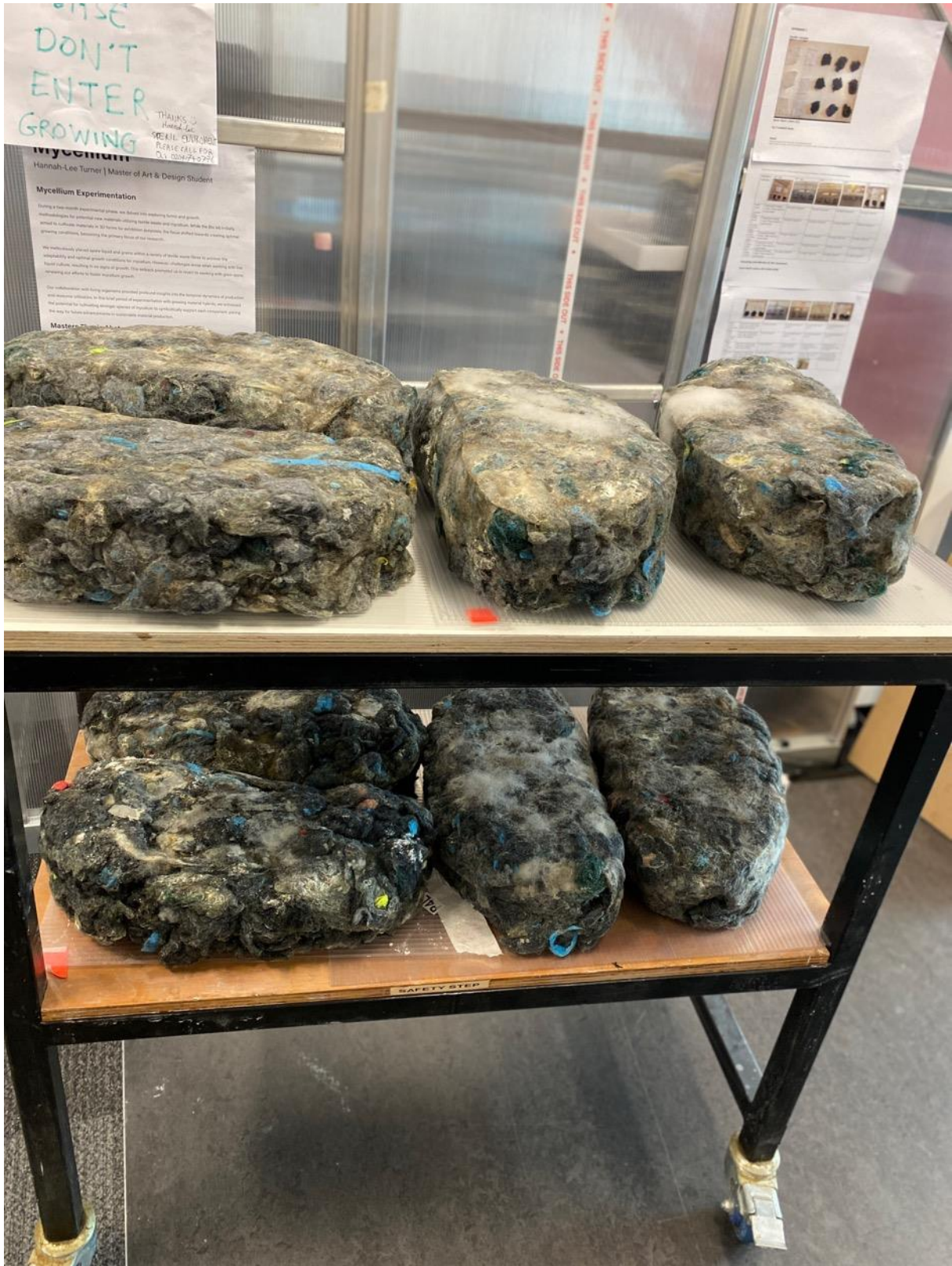
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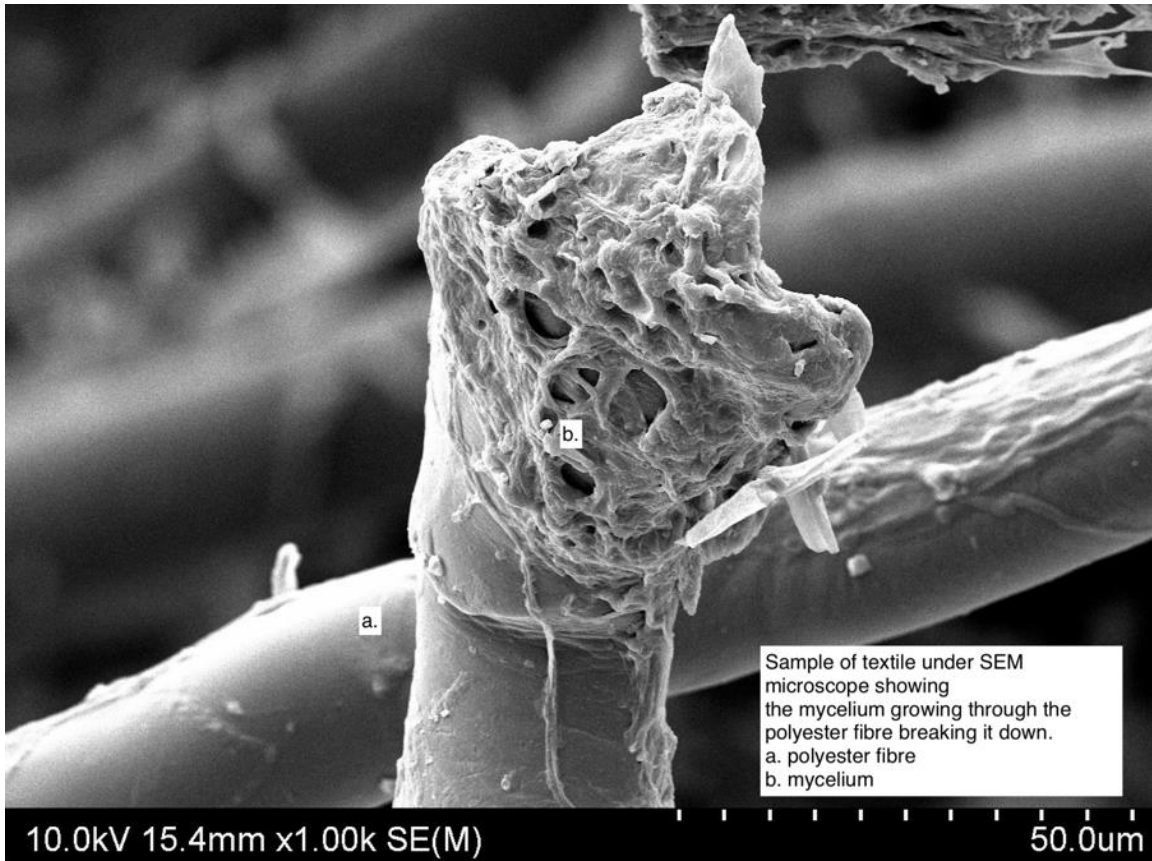
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