The Mycelium Cookbook:
A Guide for Growing Mycelium-Based Composites
for Architectural Applications

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Abstract

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Mycelium-based composites (MBCs) offer a sustainable alternative to today's building materials. Grown from fungal spores and woody substrate, MBCs require little energy, resources and labor. They are low carbon, low cost, and biodegradable, making them an attractive alternative to wasteful construction and packaging materials like insulation and styrofoam. The research and development on these materials has mostly occurred at the smaller scale, within fields of design, packaging, home goods. Within the last decade, MBCs have slowly been picking up speed in the field of architecture and engineering, although research is still very limited. To advance the research on MBCs for use in the context of architecture , the material needs to be accessible to architecture students. The majority of academic articles on MBCs is written for an audience with a background in biology, is behind a paywall, or leaves out important information because it is proprietary. Much of the information on growing is very scattered and often uncomprehensive. This research consolidates information on MBCs into a guide that architecture students can use to set up their own projects. It includes background information on the field, case studies, best practices, lab setup, and recipes to grow your own mycelium materials.

The Mycelium Cookbook:

A GUIDE TO GROWING MYCELIUM-BASED COMPOSITES FOR ARCHITECTURAL APPLICATIONS

Bella Batson

Manny Becerra / Unsplash

Contents

Introduction

Mycelium-based composites (MBCs) are materials grown from fungal spores and organic substrate. Like most bio-materials, the aim of their development is to create a sustainable alternative to contemporary materials such as styrofoam, leather, and plastic. Because MBCs are grown from living materials, they require little energy to produce, are zero to low carbon, they are cheap to grow, and they are biodegradable.

There is impressive research on mycelium-based composites (MBCs), but very little of it considers the material's role in the field of architecture. Most of the research and development has existed within the fields of packaging, home goods, and fashion. One leader in the industry is Ecovative; they produce packaging for small products and a variety of home goods. The majority of material research occurs at a small or microscopic scale. One such study grows small samples of MBC to compare the effects of straw and sawdust, and paper substrate on material strength and water absorption (Teeraphantuvat et al, 2024). Another study by Sun et al. how mycelium colonization impacts physical properties of the final sample, specifically sound absorption (Sun et al, 2022). While this is exciting progress, it is vital to invest in material research on MBCs and other bio-materials in the field of architecture. According to the Architecture 2030 Challenge,"the built environment is responsible for about 42% of annual global CO_2 emissions". Architects have a duty to reduce this percentage through designing energy efficient buildings and opting for sustainable materials. With more research and development, MBCs have great potential to replace some conventional building materials in the near future.

For mycelium-based materials to advance within the field of architecture, they need to be accessible to students. Architecture and materials science students produce innovative thesis projects and dissertations every year. Encouraging more students to explore in bio-materials in their studio projects and theses will yield more research. However, mycelium is not the easiest medium to work with, and it can take months to develop a proper lab setup and grow a successful sample. If an architecture student wants to explore MBCs in their studio project, they may find themselves spending much of their time scouring the Internet to understand mycology terminology and to find the best way to grow mycelium. Because thesis projects are only a couple quarters to a year in duration this research and setup would consume much of the time that should be spent manipulating variables to develop a better sample, growing a large-scale structure, or testing the material.

The amount of research in this field can feel overwhelming, and most of it focuses on extremely niche elements of growing, such as species and substrate selection. Additionally, most of the peer-reviewed literature falls within the field of biology and may require background scientific knowledge, which most design students do not have. And while there is a lot of great amateur research on online-forums, it can be time consuming to weed through posts and determine which information is reliable. This research aims to condense and simplify existing information on MBCs in order to streamline the initial research phase for students, so they can spend more time growing and contributing new research to the fields of MBCs and architecture. The product of this research is a comprehensive guide for growing MBCs, which will inform students on the best practices for growing MBCs from start to finish. This guide contains background information on the field of MBCs, case studies and examples of existing research projects, literature review summarizing the best practices for growing, and a section on lab setup and equipment. The guide also includes recipes with detailed procedures that students can follow to grow their own mycelium materials. The recipes are both formulated as a part of this research and sourced from other research projects. Compiling all of these recipes into one cookbook will allow students to test out multiple methods of growing.

The easier it is for students to quickly access information on sustainable materials, the more likely it is that they will explore using this material in their thesis project. MBCs are still in the early stages of development, and there is much to be explored in terms of their use as a building material. This will generate more discussion and research on MBCs within the field of architecture.

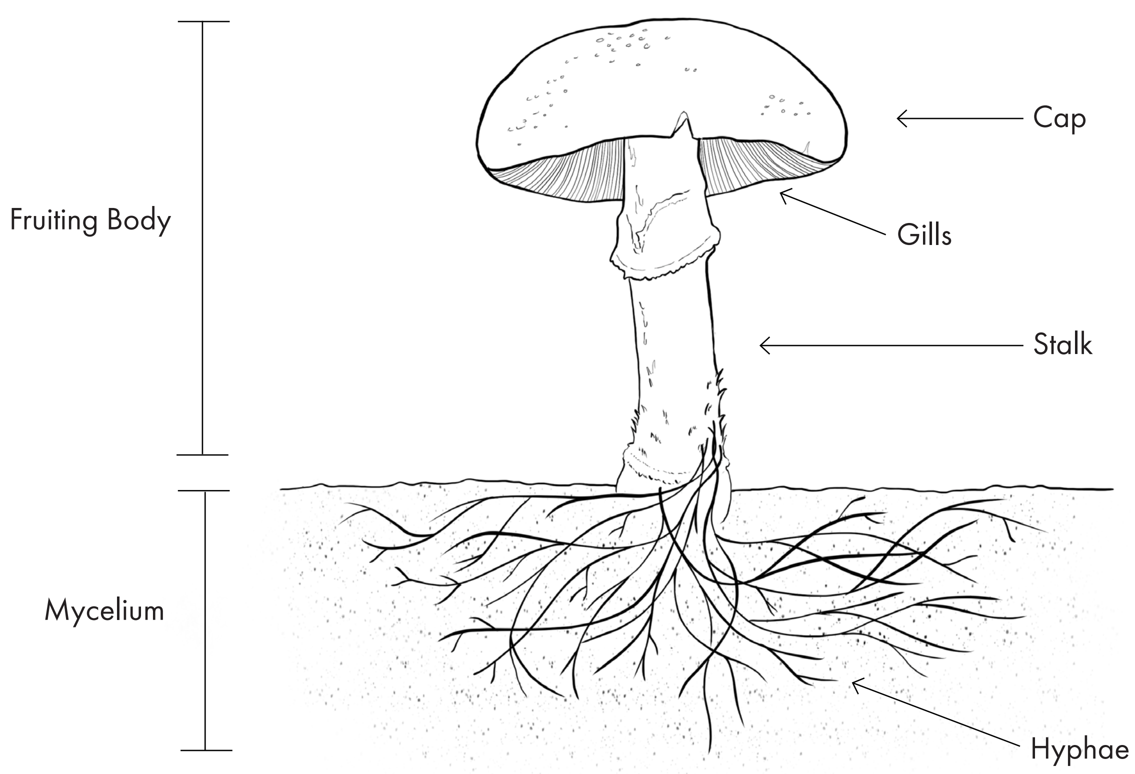
PART ONE

MYCELIUM AS A MATERIAL AND ITS APPLICATIONS IN THE BUILT ENVIRONMENT

Background

WHAT IS MYCELIUM?

When we imagine a fungus, we typically picture an edible mushroom like a button mushroom, crimini, shiitake, or portabella. But these delicious mushrooms only represent one part of the larger organisms called fungi. These delicious, flashy structures are the reproductive part of the fungus, also called the fruiting body. Inside the stalk of the mushroom and below ground are Hyphae. Hyphae are thread-like filaments made of fungal cells. Mycelium is the mass of hyphae. A fungus contains many hyphae, but only one mycelium. Depending on the type of fungus, its cap contains gills, pores, or teeth, which produce and release reproductive cells called spores. These spores will disperse, germinate, grow into mycelium, and develop more fruiting bodies. Mycelium grows rapidly and feeds off of dead and decaying matter to absorb nutrients.



WHAT IS AN MBC?

Mycelium-based composites (MBCs) are materials grown from fungi and substrate. The substrate provides the fungal spores with nutrients, thus growing mycelium; a root-like network of thread-like hyphae which grows between the substrate, holding it all together. In addition to fungal spores and organic substrate, MBCs require time and care. The fungal spores need time to grow into mycelium. The mycelium is then added to the substrate and will require an additional week or two of grow time. As for care, growers will need to check on their samples every day to ensure healthy development. The mycelium needs moisture, fresh air, and controlled temperatures. For a grower, this will involve soaking the substrate, misting the samples, circulating air by way of a fan, and knowing the difference between healthy mycelium and mold.

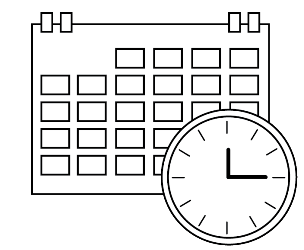
Northspore

Fungal Spores

+

Organic Substrate

+



Time & Care

=

Building on Mycelium by Ilse

Mycelium-based composite

OUR CONSTRUCTION PRACTICES ARE UNSUSTAINABLE

There is so much waste involved with every stage of construction, waste that will not break down within our lifetimes. This waste comes in the form of material packaging, unusable offcuts of building material, material that doesn't meet quality requirements, and waste from demolished projects. What if this waste was biodegradable? MBCs could replace some of these materials, eliminating the garbage produced from many construction activities. In 2018, the EPA reported a sum of 600 million tons of construction and demolition waste in the USA. This is more than twice the amount of municipal solid waste. While 455 million tons of the waste was sent to be reused or recycled, 145 million tons was sent to landfills. The EPA reported that demolition was responsible for 90% of the waste and construction was responsible for 10%. Of the 600 million tons of waste, 67.5% was concrete, 17.8% asphalt concrete, 6.8% wood byproduct, 2.5% asphalt shingles, 2.5% drywall and plasters, 2% brick and clay tile, and 1% steel (EPA, 2018).

Styrofoam can take 500 years to breakdown. When plastics break down, they don't just disappear, they desintigrate into micro plastics that make their way into our watersheds, food systems, and even our bodies. Buildings also use a lot of manufactured wood like OSB and plywood. Engineered woods like these contain formaldehyde and VOCs.

Ellen N Banner, The Seattle Times

Many adhesives found in manufactured wood contain formaldehyde and VOCs

pcess609 / iStock

Plastic waste breaks down into micro plastics

Wokephoto17 / Getty Images

Styrofoam can take 500 years to break down

Ellen N. Banner, The Seattle Times

WHY MYCELIUM?

Within the field of MBCs, it is widely accepted that the primary motivation for their advancement is to create a sustainable alternative to contemporary construction materials and associated construction waste. They require little to grow, as the mycelium feeds on agricultural waste. Specifically, mycelium feeds on lignocellulosic biomass, which is a carbon-neutral, renewable resource. This type of substrate is also very cheap and abundant.

BIODEGRADABLE

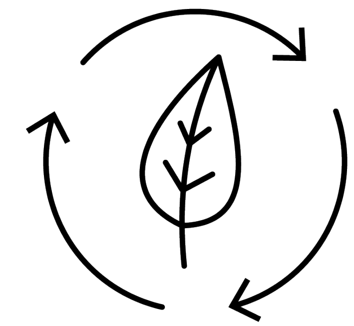
MBCs are made entirely from organic matter. This means they are biodegradable. In some cases they can also be compostable, depending on the processes used to grow them and if there are any non-compostable additives.

LOW CARBON

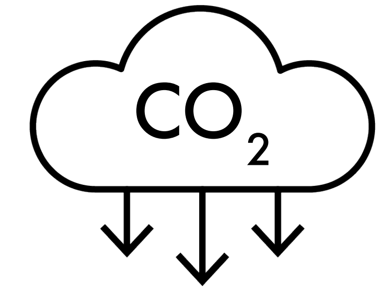
Mycelium requires very little energy to grow. A large scale operation like a laboratory or a company that grows and sells mass amounts of MBCs may require a significant amount of energy, but this would still be far less energy than to produce concrete or styrofoam

CHEAP TO PRODUCE

MBCs are extremely cheap to produce, especially when compared to other construction materials. This is due to a few reasons. First, mycelium requires very little to grow. The organism only needs organic material to feed on, moisture, fresh air exchange, normal room temperature, and low light. Substrate can cheaply be obtained as agricultural waste. Second, mycelium does not require much attention, meaning low labor costs. Third, it does not require much energy. At a large scale lab, they would need to regulate temperature, humidity, and air circulation. A research study even suggests that "using bio-materials can reduce costs about 80 times lower than conventional materials. Biological construction materials can reduce carbon emissions nearly by 800 million tons per year" (Alemu et al, 2022). This research team estimated a mycelium-based block to cost $18.92 USD per m3, and a cement-based block to cost $936.87 per m3. The fabrication process is also very low-tech and cost effective. While there are a multitude of ways to fabricate MBCs, they mostly depend on form work made from wood, plastic, or silicon. These molds are inexpensive and can be reused again and again.



Biodegradable
(can be compostable)



Zero to low
carbon output

Cheap to produce

EVOLUTION OF MBCs

Like many bio-materials, mycelium-based composites started out in the field of industrial design for small scale products such as packaging, faux leathers, and plastic alternatives. And as research on the compressive strength and structural qualities of MBCs advances, they are slowly integrating into larger scale fields like furniture and construction. MBCs have advanced in terms of their compressive strength. A material which started at the scale and weakness of single use packaging has evolved to the architectural scale, now being used to build temporary structures. But this is a slow process. Little research has been done in the field of architecture and building, most of the exploration in myco-materials has been for the fabrication of small scale objects, such as 3D printed furniture, chairs grown in plastic form work, and even a canoe.

Some of the big players in the world of "myco-materials" are Ecovative, Mycoworks, and Mogu. It is a common practice for researchers to buy pre-made grow kits from companies such as Ecovative. This is a great option if the research focuses on design and form, however this limits the researcher's ability to manipulate the material. The purpose of this guide is to make it easy to grow a project from start to finish.

Ecovative

Ecovative

Magic Mushroom Co

Ecovative

Mycelium Leather by Mylo

Pottery by Craft Combine

Lamps by Sebastian Cox

Mycotexture chair by Phil Ross

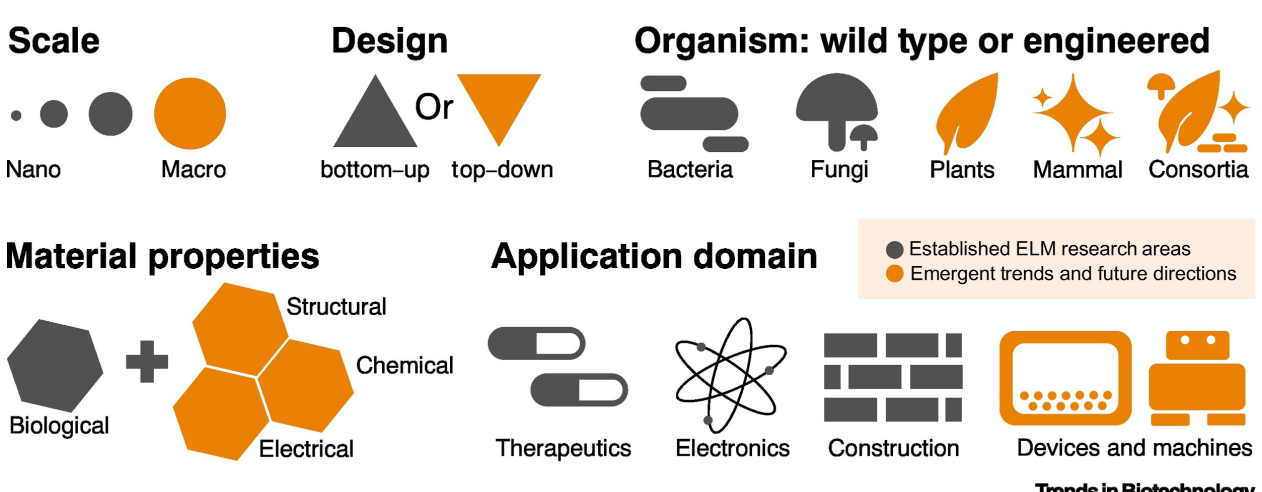
MYCELIUM AS AN ENGINEERED LIVING MATERIAL (ELM)

"ELMs are more formally defined as engineered materials composed of living cells that form or assemble the material itself and modulate the functional performance of the material post production" (Will V. Srubar, 2021). An ELM is composed of two parts: Living cells and supportive scaffolding. For an MBC, the mycelium is the living cells and the substrate is the supportive scaffolding. ELMs are typically designed to respond to environmental stimuli such as light, humidity, and temperature.

In *Engineered Living Materials: Taxonomies and Emerging Trends* by Will V. Srubar, he created an info-graphic to illustrate taxonomic classification of ELM research. These taxons include scale, design process, type of organism, material properties, and the field for which the material is designed. To date, most of the research in ELMs work at a very small scale or microscopic scale. These projects engineer bacteria, fungi, and plant cells for applications in medicine, electronics, and built environment.

A similar area of study is called biomimicry Elena Luri-Luke's article titled *Product and Technology Innovation: What Can Biomimicry Inspire?* defines biomimicry as a growing field that seeks to interpolate natural biological mechanisms and structures into a wide range of applications". In her article, she surveys material research classified as biomimicry, assesses emerging trends, and imagines potential future applications. Examples include adhesives inspired by mussels where fluid changes to gel depending on the pH, materials made hydrophobic using a coating inspired by the waxy cuticle on lotus leaves, and Nissan's crash avoidance laser range finder inspired by the visual systems of bumblebees. Like ELMs, the field of biomimetics serves as a source of inspiration to design materials that respond to their environment.

One example of the application of fungi as an ELM is in self-healing concrete.



Will V. Srubar, 2021

CASE STUDY:

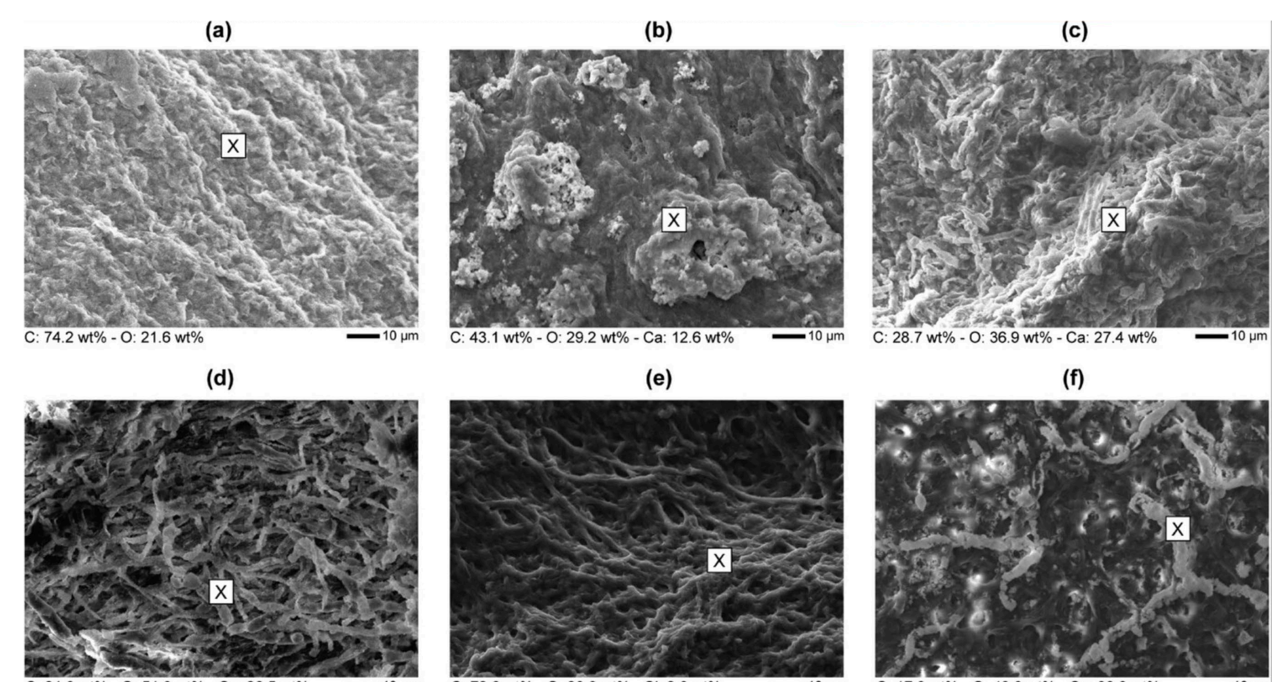
Conditions for CaCO3 Biomineralization by Trichoderma Reesei with the Perspective of Developing Fungi-Mediated Self-Healing Concrete by Wylick et al.

Biomineralization is the process by which living organisms produce minerals, often resulting in hardened or stiffened mineralized tissues. Fungi would serve as the self-healing agent in self-healing concrete. When the concrete cracks it allows water and oxygen in, which triggers the fungal spores to germinate, grow, and precipitate calcium carbonate crystals to mend the cracks. The goal of Wylick et al was to identify optimal conditions for $CaCO_3$ precipitation by the fungal species *Trichoderma reesei*.

Researchers incubated *Trichoderma reesei* liquid culture with cement paste to simulate a concrete environment. They conducted two experiments where they changed both the calcium source and nutrient source to observe their effects on fungal growth and $CaCO_3$ precipitation.

The first experiment tested two different sources of calcium: calcium chloride ($CaCl_2$) and calcium lactate (CaL). CaL was identified as the best medium. In the second phase, they tested a variety of nutritional mediums: corn steep liquor (CSL), malt extract (ME) and potato dextrose broth (PD). Potato dextrose broth was identified as best for fungal growth.

Researchers utilized Scanning Electron Microscopy with Energy Dispersive X-ray Diffraction to observe the morphology of fungal hyphae and the presence or $CaCO_3$ crystals. The photos to the right visualize the presence of $CaCO_3$ crystals for each combination of mediums.



Wylick et al, 2023

PLASTIC-EATING MYCELIUM

One variable that can be manipulated to change an MBC is substrate. What if plastic waste could be fed to mycelium instead of natural substrates? This would provide a way to make use of our plastic waste while creating a new material.

CASE STUDY 1:
Fungi Mutarium by Livin Studio

In partnership with Utrecht University, Livin Studio created a prototype to facilitate the growth of edible fungi biomass by feeding plastic bags to fungi. They first created small, cup-shaped pods referred to as "FU". The "FU" are made from agar, glucose, and starch and are meant to contain the plastic while providing surface area and structure for the fungi to grow on. Before placing the plastic in the FU, researchers treat the plastic with UV light to sterilize it and activate degradation process to make it easier for the fungi to break down. The fungi digests the plastic and colonizes the "FU". After a couple weeks, the FU is ready to be harvested and eaten.

CASE STUDY 2:
Degradation of Oxo-Biodegradable Plastic by Pleurotus ostreatus by da Luz et al

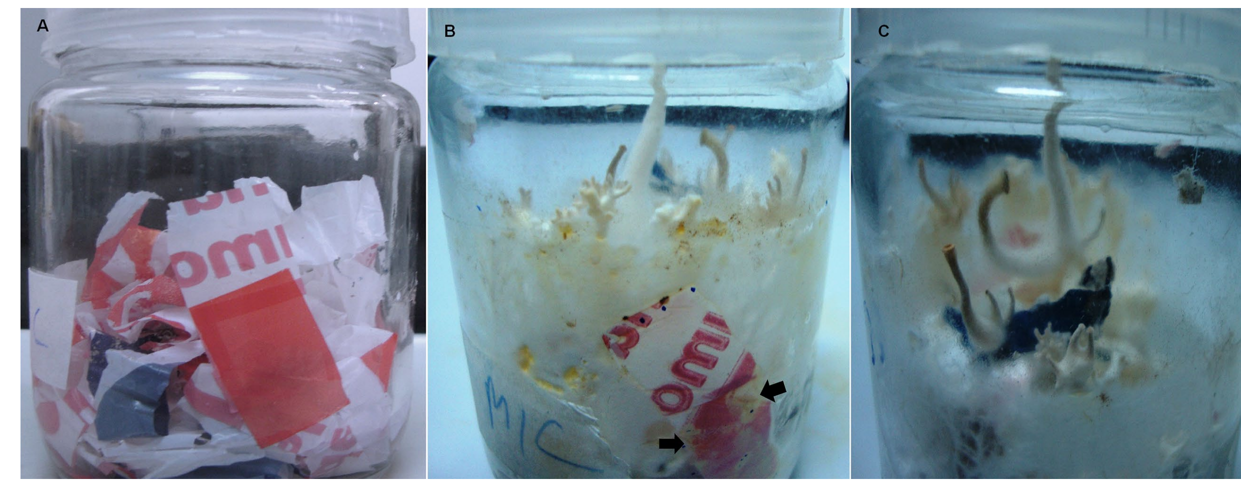
In this study, oyster mushrooms were found to degrade biodegradable plastic bags. The research team used Oyster mushrooms, which are commonly used in MBCs. For the plastic, they cut up common oxo-biodegradable grocery store bags into small fragments. In a glass flask, the researchers added mycelium, 5mL of a mineral medium, 10g of plastic, and 0.1g of paper towel to retain moisture. The flasks and contents incubated at 25°C (77°F) for 45 days to achieve fungal growth. The team observed holes, cracks and discoloration in the plastic and that the fungus colonized its surface. The research team concluded that "P. ostreatus is capable of degrading oxo-biodegradable plastic and producing mushrooms using the plastic waste without any prior physical treatment" (Luz et al, 2013).

CASE STUDY 3:
Biodeterioration of pre-treated polypropylene by Aspergillus terreus and Engyodontium album by Samat et al

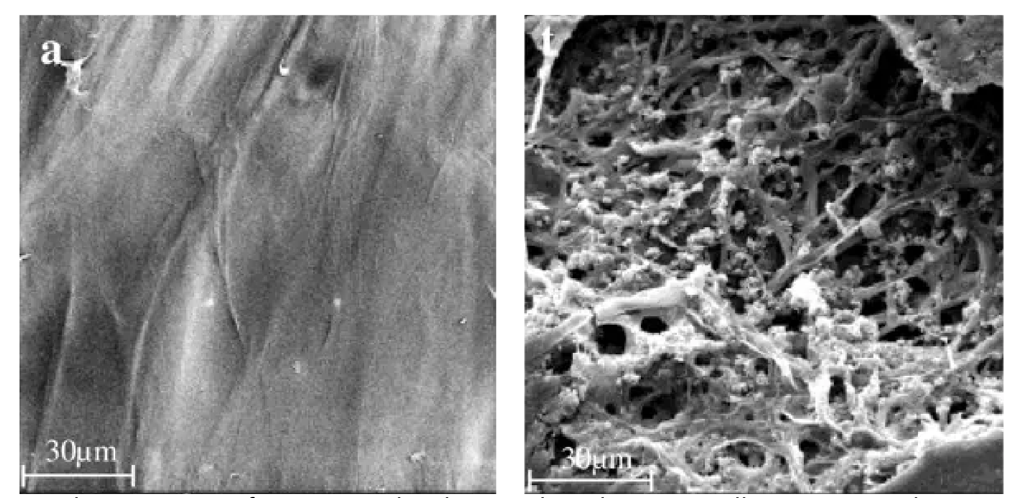
Samat et al were successful in developing a process to degrade everyday plastic using fungi. The photos show the plastic before and after being degraded by the fungus.

This study used Aspergillus terreus and Engyodontium album, which are much different fungal species than what are used in MBCs. The researchers used polypropylene in three different forms: film, metallised film, and granule. They also explored different ways of pre-treating the polypropylene to make it easier for fungi to break down. These methods included UV light, heat, and fenton's reagent, an acidic solution of hydrogen peroxide and ferrous iron (Low, 2023). They fed the pre-treated polypropylene to the fungi and incubated for 90 days. To observe degradation, researchers measured weight loss of the polypropylene and used electron microscopy scanning to observe surface changes.

Fungi Mutarium by Livin Studio



Degradation of Oxo-Biodegradable Plastic by Pleurotus ostreatus by da Luz et al



Biodeterioration of pre-treated polypropylene by Aspergillus terreus and Engyodontium album by Samat et al

PLASTIC EATING MYCELIUM

MYCO-PLASTIC COMPOSITES

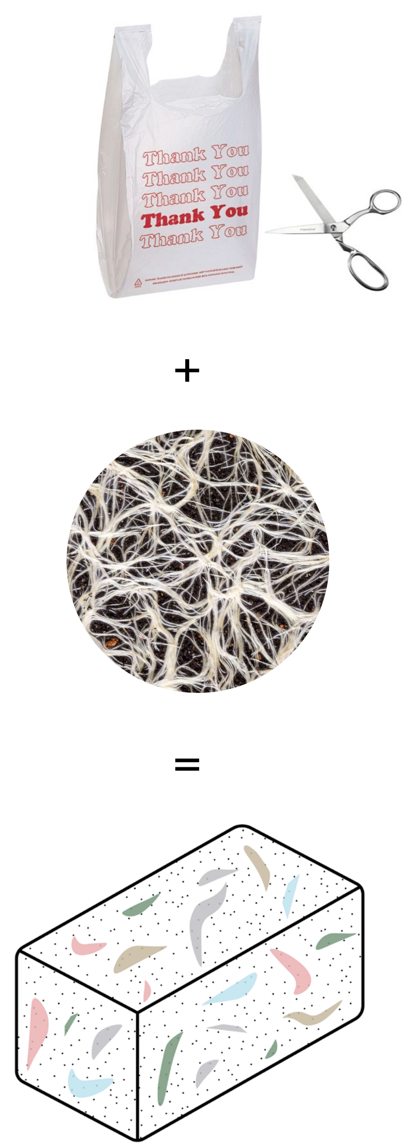
The previous case studies have already found that various species of fungi have the ability to break down plastics, ranging from biodegradable plastic bags to polypropylene. However, these studies were not looking for a way to make a new material, they were researching mycoremediation, food production, and ways to address plastic waste. All this research proved that fungi can be trained to feed on plastics. The next step is using it to create a material.

An MBC that uses plastic could be treated similarly to an MBC that uses natural substrates. It could still be shaped using block molds and curved surface molds. For fabric grown MBCs, the plastic could potentially serve as both the fabric form work and the substrate. Plastics bags could be woven together to form a layer, on which mycelium will grow.

When making an MBC using woody substrates, they are typically baked in the oven to halt all growth. The substrate is still visible in the end material, because not all of the straw or sawdust is broken down. The remaining substrate helps provide strength to the composite. This presents an issue for MBCs made from plastic. Plastic cannot be baked in an oven, it will melt. The material would either have to be dehydrated or the mycelium would have to degrade all of the plastic before being baked, which could result in a weak composite.

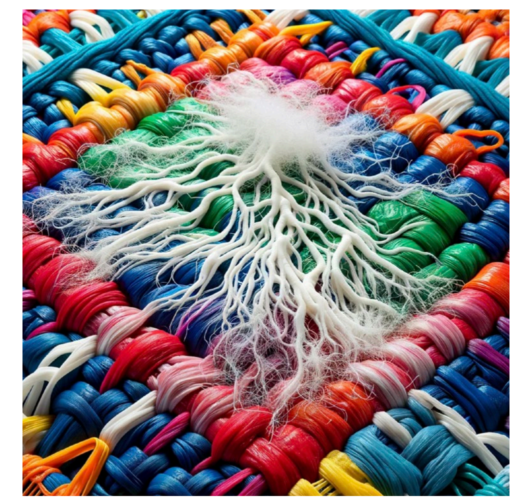
AI GENERATED IMAGES ▶

These six images were generated using Chat GPT 4. They imagine what materials made from mycelium and plastic could look like. Maybe shredded plastic replaces natural substrate, or plastic is woven together to create a net that mycelium can grow on, and maybe the colorful plastic is still visible in the final composite for visual interest.




Shredded plastic bags


Mycelium growing on shredded plastic bags


Mycelium growing on a textile made from plastic bags woven together


Block made from mycelium and plastic


Blocks made from mycelium and plastic assembled into a wall structure


Chair made from mycelium and pieces of plastic

PURE MYCELIUM

What if we removed the substrate all together, just leaving the mycelium? Mycelium leather is made by doing just that. Although it still needs to be fed, the substrate is not present in the final material. In many cases, the mycelium is fed a liquid mixture such as malt. Spores or placed into a container with the malt mixture and mycelium begins to grow at the top of the liquid. After growing into a foam-like structure, the mycelium is removed from the malt mixture, dried and heat pressed. The result is a flat, rubbery sample of material.

This technique is still rather young. There are only a few brands on the market that sell mycelium leather and they keep their process secret. Mycelium leather currently exists at the scale of wearable accessories like handbags. When imagining its application in the context of architecture, the production process must be developed to achieve larger and stronger pieces of fabric.

Two of the following case studies grew their mycelium in jars, which results in small, disc shaped material samples. Students could further this research by experimenting with different shapes and sizes of containers.

CASE STUDY 1:
Mycelium Leather by VTT

VTT's process allows them to make long, narrow sheets of mycelium leather with the help of a large heat press. This "leather" can be as strong as animal leather and is intended for footwear, garments, and accessories.

CASE STUDY 2:
MycoTEX by Aniela Hoitink

MycoTEX creates fabric from mycelium to make garments. They have no textile waste, because the material is grown, rather that cut from a sheet. After being worn, the garment is meant to be buried and decompose. These mycelium material samples are frown in jars as discs, which are then grown together to create a dress.

CASE STUDY 3:
The Purhyphae Project by Annah-Ololade Sangosanya

Similar to MycoTEX, this student project at the Fabricademy Barcelona explored growing pure Reishi and Oyster mycelium in jars on a liquid malt medium. The samples were then heat pressed and coated in beeswax resulting in a translucent, flexible material. The photo on the bottom right shows the mycelium after being removed from the malt mixture, before any post-processing.

Mycelium Leather by VTT

MycoTEX by Aniela Hoitink

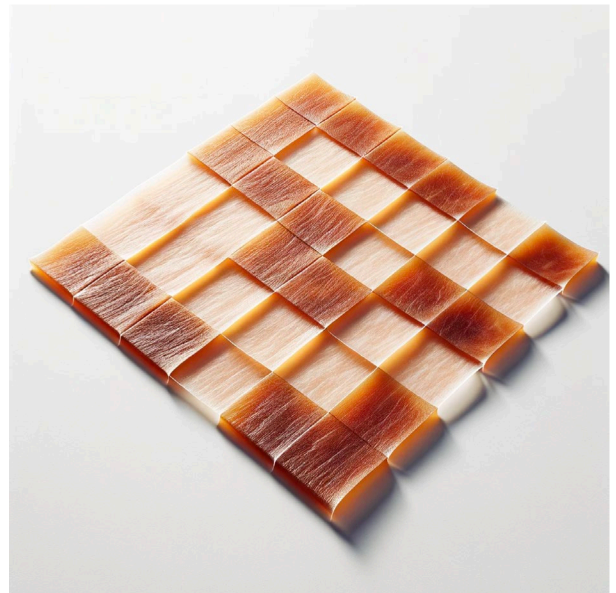
The Purhyphae Project by Annah-Ololade Sangosanya

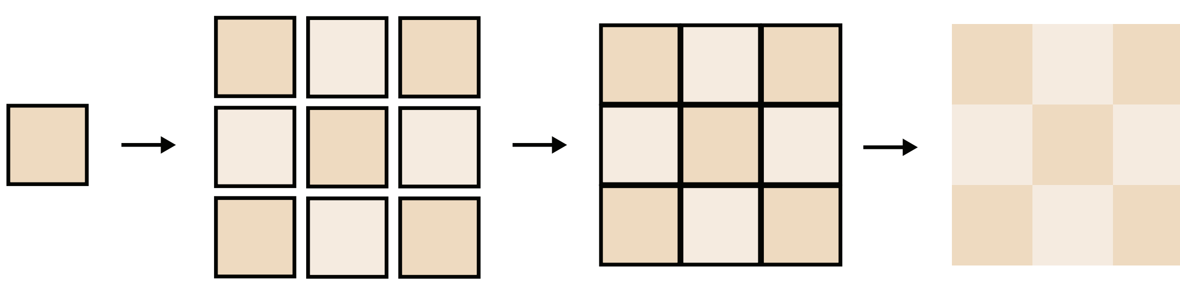
PURE MYCELIUM

MYCELIUM QUILTING

One issue with the production of mycelium leather is that it is 2D, planar material, which limits its size. It would be difficult to make a large sheet of mycelium leather. But what if there was a way to make a seamless fabric at an architectural scale?

Mycelium quilting is a concept similar to bio-welding, in that it allows multiple samples of mycelium-based composites to grow together, creating a singular form. Mycelium quilting treats the composites more like fabric and uses many small samples in a checkerboard pattern. Through this process, researchers can use small 3D printers or molds to make the initial samples and end up with a larger composite. This method could eventually be used to make larger fabrics for an architectural context, such as sun shades and room dividers


AI generated image of mycelium quilting



Grow a square-shaped sample of mycelium

Grow more samples of the same size

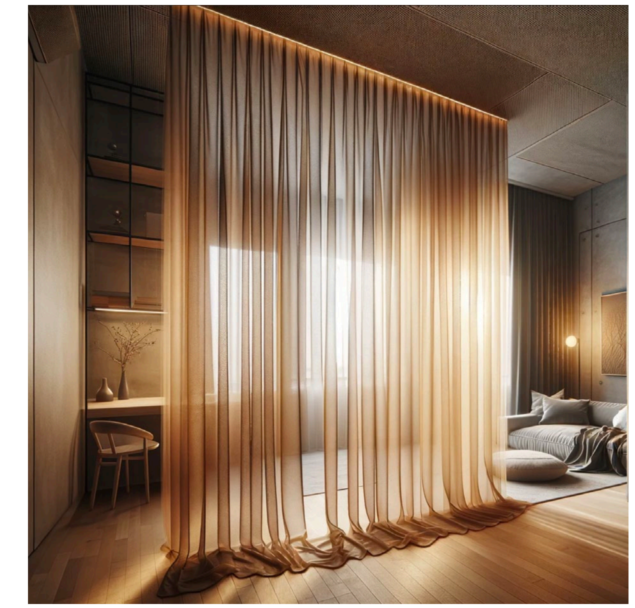
Place squares adjacent to each other, allowing them to grow together

Samples fuse together, creating seamless bonds

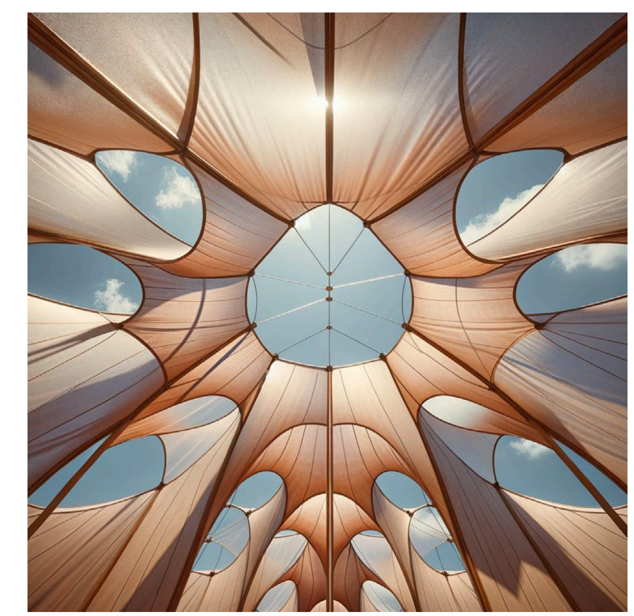
AI GENERATED IMAGES

These images were generated using Chat GPT 4. They imagine what materials made from pure mycelium could look like when applied to home goods and architecture. Pure mycelium can have a translucent quality, which could make a great lampshade, curtain, or shading device.


Translucent lampshade


Curtains


Shading devices


Tent-like shading device

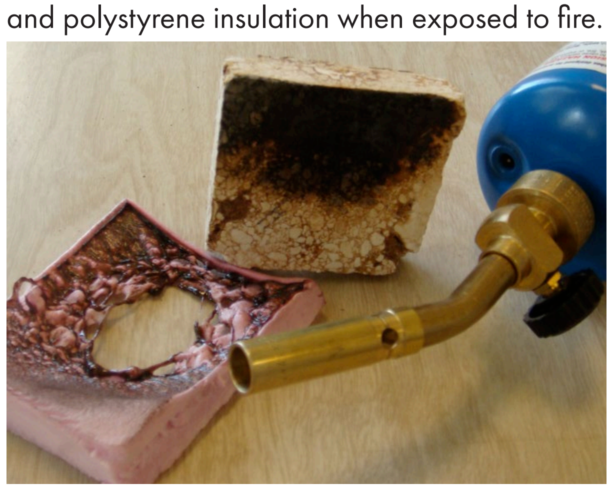
MATERIAL PROPERTIES

ADVANTAGES

Mycelium-based composites are lightweight and low density. The material is very foam-like, which can definitely be used to our advantage.

Because of its foam-like quality, MBCs have high acoustic absorption and thermal insulation due to the small spaces between the substrate and mycelium. In an article titled *Insight into mycelium-lignocellulosic bio-composites: Essential factors and properties*, they concluded, "the lignocellulosic substrate and gaps between particles played an essential role in the sound absorption and thermal insulation properties of the foam, as a denser mycelium structure negatively affected these properties" (Sun et al, 2022).

According to Jones et al, MBCs also have "fire safety properties outperforming traditional construction materials, such as synthetic foams and engineered woods". Ecovative tested the fire safety of their mycelium insulation called Greensulate. They found that the material does not ignite or melt, it only chars (Wilson, 2024). The photo below compares mycelium insulation and polystyrene insulation when exposed to fire.



Ecovative

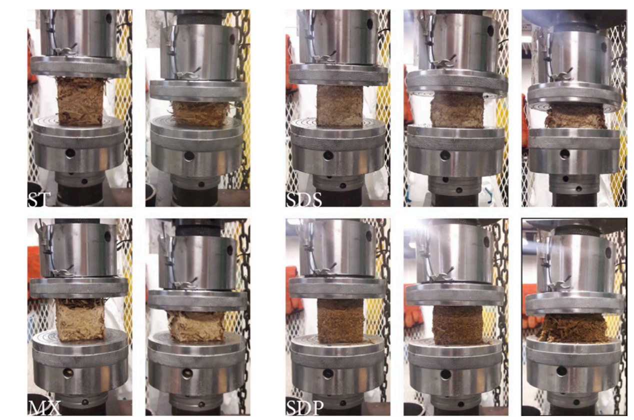
LIMITATIONS

While there are exciting advantages to MBCs, the material has significant limitations. MBCs have similar mechanical properties to foam. This results in limitations such as high-water absorption and low strength (Jones, 2020). Although mycelium is extremely strong relative to its weight, it is nowhere near as strong as construction materials like concrete. MBCs show great potential for use as construction material, but not as a structural or weight-bearing member.

Mycelium itself is water resistant, water beads off of its surface. However, the woody substrate in MBCs is very water absorbent. If the composite is completely covered in mycelium, so that no substrate is visible from the outside, MBCs are much more hydrophobic. In a research paper titled, *Improving the Physical and Mechanical Properties of Mycelium-Based Green Composites Using Paper Waste*, Teeraphantuvat et al studied the use of corn husks, saw dust, and paper waste as substrates and how that affects the material properties of an MBC. They found that the use of hydrophobic coatings, mycelium species, substrate species influence water absorption. They also found that low porosity, high density MBCs absorb less water. Teeraphantuvat et al also suggests that water absorption could be considered advantageous when used in packaging for liquids. The MBC packaging could absorb any leaks when transporting the liquid products.

Water absorption is not ideal for most applications, especially for building materials. MBCs could potentially be used for temporary outdoor structures or even form work for wet materials like concrete. Because the material will absorb moisture, MBCs are not a great choice for exterior elements like cladding.

In a research study called Mycelium-Based Bio-Composites For Architecture: Assessing the Effects of Cultivation Factors on Compressive Strength, they grew a variety of MBCs and tested them for strength. The samples had varying amounts of sawdust, wheat bran, and straw. The tests showed that the higher density samples, which were samples containing sawdust, could bear the most weight. The strongest sample was composed of 90% sawdust and 10% wheat bran and could withstand 1380.6 KPA before breaking. The strongest straw sample was 90% straw and 10% wheat bran and could withstand 169.2KPA before breaking. While the straw samples were weaker in compression, they showed elastic behavior which makes them a good substitute for foam (Ghazivinian et al, p. 11). Overall, they concluded that "although the straw-based and mixed specimens show a quite well elastic behavior, their compressive strength was very low to be used in masonry constructions. Moreover, while the sawdust-based specimens yield higher compressive strength, they are also not strong enough to replace conventional masonry materials without introducing any reinforcement" (Ghazivinian et al p 512). Despite the low compressive strength of their samples when compared to traditional masonry, this research team maintains that with further development, MBCs are potential substitutes for masonry.



Ghazivinian et al. compression tests
ST: Straw, SDS: sawdust with supplements, MX: equal parts sawdust and straw, SDP: sawdust

Material Properties of MBCs	
Advantages	Limitations
Low thermal conductivity	Low density
High acoustic absorption	Weak, non-structural
Fire retardant	High water absorption

WHAT BUILDING MATERIALS CAN MBCS BE USED FOR?

MBCs can be used for "foams, timber and plastics for applications, such as insulation, door cores, paneling, flooring, cabinetry and other furnishings" (Jones, 2020). MBCs have very low thermal conductivity and high acoustic absorption, making them well suited for thermal and acoustic insulation. MBCs have similar mechanical properties to foam, which results in many limitations. However, the material's foam-like properties can also be seen as strength; foams are needed for a wide range of applications in construction.

INSULATION

Multiple companies have already developed or are in the process of developing insulation made from mycelium. It offers an exciting and sustainable alternative to traditional foam insulations. MBC insulation has not taken off as a standard products, but further research and development could lead to a product that is more affordable for developers.

ACOUSTIC PANELS

The low-density of MBCs makes them a great absorber of sound. They serve as a great alternative to standard acoustic panels, which are typically made of foam or thick, cushy fabrics like felt. Like foam, MBCs are grown in a mold. This allows their processes and design to remain similar.

Acoustic Panels
Mogu makes tessellating acoustic panels in a variety of colors (Mogu, 2022).

TEMPORARY STRUCTURES

A few research teams in the fields of architecture and engineering have explored growing MBCs at a larger scale to build temporary structures or exhibitions. Because mycelium is rather weak, these structures are either modeled from strong geometrical forms or utilize wood framing to support the MBC.

ANYTHING FOAM-LIKE

Because MBCs have a very foam-like quality, they should be used for non-structural filler materials. Foam has many uses in a building. One example is door cores. Interior doors could be filled with lightweight MBCs instead of particle board or mineral core, or honeycomb hollow core. In construction, foams are often used to fill up gaps before being covered with drywall wall. Because MBCs are insulative, this makes them a very good option to fill these small gaps.

PACKAGING

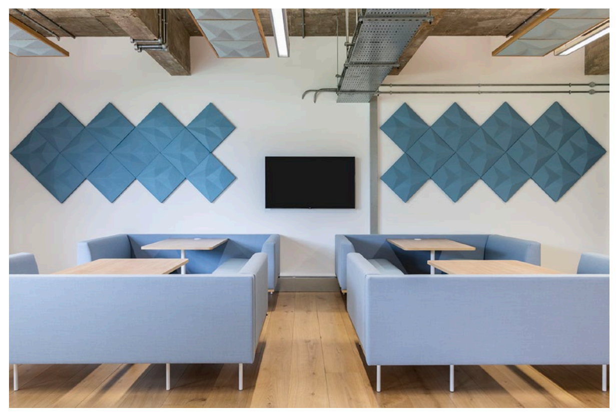
MBCs should be used as packaging for construction. Every construction site has a big pile of discarded styrofoam packaging used to safely transport construction materials. Brands like Ecovative are proof that MBCs are an effective alternative to styrofoam packaging. The companies that produce and sell the MBC packaging are only doing so at the scale of small products, but it is time to scale up the operation to supply packaging not only for larger products like Televisions and refrigerators, but also for construction materials like tiling, glass, and metal components. .

EXAMPLES OF EXISTING PRODUCTS

Greensulate

Currently a prototype made by Ecovative, this is a great example of how MBCs could replace certain elements of the building envelope, such as insulation. Greensulate is an R-3-per-inch rigid insulation made from seed hulls and mycelium. Greensulate can char in the event of a fire, but it will not melt or ignite like Polystyrene (Wilson, 2011).

Mogu Acoustic Panels



These modular acoustic panels are available for home and office use. They come in an array of colors and geometric shapes. Mogu's acoustic panels are made from soft mycelium material and up-cycled textile residues (mogu, 2022). The company attributes their sound absorption to the velvety finish and 3D shape.

Mycoworks x Ligne Roset

Mycoworks partners with fashion brands to help them make products and garments using their mycelium leather, Reishi™. In January 2024, they entered a partnership with Ligne Roset to upholster their infamous Togo chair with Reishi mycelium leather. This chair is commercially manufactured at a large scale.

Zero-Frm Wall Paneling System

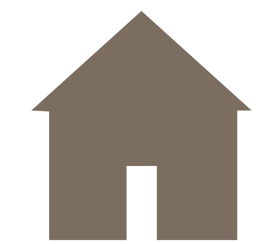
Okom Wrks Labs claims to have developed a structural mycelium-based composite. With this material, they have designed a patent-pending, modular wall panel system. Their MBC is made from three ingredients, although their descriptions are extremely vague. The first ingredient is of course mycelium, but they do not specify the species. The second ingredient is "agri residue", which provides reinforcement. The third ingredient is a textile, which they say is used "for a little nano magic" (okomwrks.co).

METHODS OF FABRICATION IN LARGER STRUCTURES

Research teams developing mycelium ELMs take their project a step past merely growing an MBC, they also integrate the use of technology. Projects often employ digital fabrication techniques such as 3D printing to print the actual mycelium, or CNC routing and laser cutting to cut complex form work. Using 3D modeling software and parametric design, they opt for strong geometrical shapes.

This literature review has identified three types of fabrication: 1) assembly; 2) monolith; and 3) bio-welding. Assembly is when a collection of bricks or building components are grown separately in molds and later assembled. Monolithic structures are grown as a single, large volume using form work, similar to cast concrete. Bio-welding is when multiple forms are first grown separately and then grown together in a process called bio-welding. These three methods look drastically different from each other and their appearance could vary even more when combined with a variety of fungal species and cultivation techniques. The following case studies serve as a source of design inspiration to help students develop methods of growing. These could be applied at a smaller scale for building studio models.

Block assembly



Monolith

Bio-welding

◀ **La Parete Fungina**
By Jonathan Dessi-Olive

ASSEMBLY

Created for the 2014 MoMA's Young Architects Program, HyFi was designed by The Living. They collaborated with Arup for structural engineering services and sourced their mycelium from Ecovative design. The goal was to make a tower out of mycelium-based composite bricks, and build it as tall as possible. 10,000 bricks form a 40 ft tall structure with a carbon footprint close to 0. The structure is widest at its base for stability, and narrows near the top. The openings at the top and in the brickwork allow for daylight and airflow. The structure is self supporting and can withstand 65 mph gusts of wind. This project appears to use parametric design. While composed of rectangular bricks, the structure resembles the hollowed-out base of a three-trunked tree.

MoMA PS1 Gallery Pavilion, 2014

MONOLITH

Jonathan Dessi-Olive, director of the Myco Matters Lab, explores the use of geometry in designing form work for large-scale, temporary structures made from MBCs. His research "focuses on overcoming (1) the challenge of cultivating large colonies of living myco-materials into precise forms and (2) the need for intuitive and re-usable form work systems that reduce waste byproducts from growing and fabrication processes". Dessi-Olive directed a team of students to produce two wall prototypes. The first prototype, "La Parete Fungina", employs myco-welded slabs. The second prototype, "L'Orso Fungino", uses monolithic fabric forming of units that are stacked and post-tensioned. The team ordered fungi from Ecovative, and says this fungi is of the Basidiomycota phylum and its "fruiting bodies resembled the brackets produced by reishi", though they do not specify which species it is.

The most impressive of his projects is called "El Monolito Micelio" (Dessi-Olive, 2019). It is the culmination of all his previous experiments in monolith myco-structures.

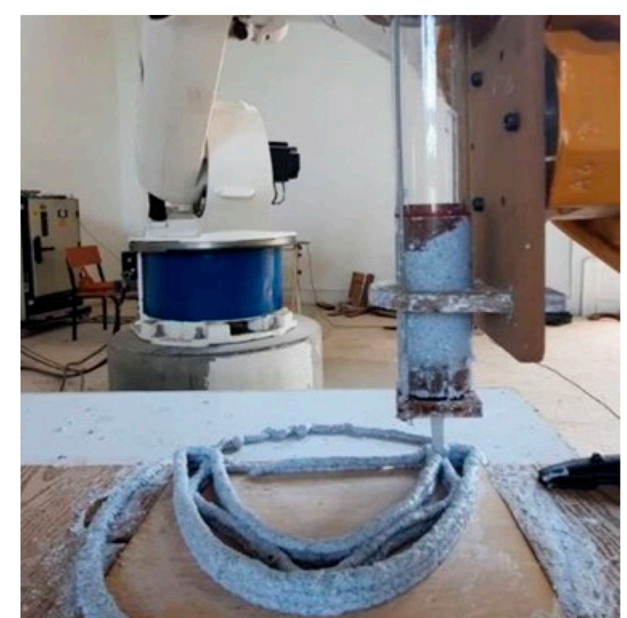
Jdovaults.com

BIO-WELDING

Bio-welding is an exciting area of study, because it allows for the joining of MBC materials or blocks without any additional binding agents or connections. Imagine if we could make a brick wall without mortar, that a hundred bricks would fuse into a single monolith.

A research team in Basel, Switzerland explored bio-welding, 3D printing, and the use of strong geometry in their design. They first experimented to develop an MBC that could be 3D printed. To test the effects of substrate, they used three categories; wood waste and sawdust produced in carpentry, municipal waste (e.g. paper, cardboard, egg cartons), and agricultural waste (severed stems of harvested plants, wheat straw, barley, sugarcane pulp, oilseed pulp) (Modanloo et al, 2021). For the species of fungi, they chose to use *Pleurotus ostreatus*. This experiment found mycelium-based composite blocks grown from the paper based substrate in combination with a guar gum gelling agent to be the most suitable option for 3D printing.

The researchers first let the inoculated substrate grow in bags for two weeks. They then used that material to 3D print a series of six identical, small arches modeled off a catenary curve. After printing the MBC material, they let the arches sit and grow for five weeks. After those five weeks, they initiated the process of bio-welding, and assembled the arches on top of each other. After seven days, the living material grew together, transforming six arches into one vault. As this is an early study in 3D printing and bio-welding of MBCs, they are entirely concerned with function and strength. While this paper experimented with many different steps in their process, such as substrates to find the optimal printing material, tested ways to 3D print, and tested shapes for the optimal form, they did not consider the aesthetic qualities of the material. The final forms have a very rough, mud-like quality. There is massive potential to explore means of enhancing the appearance of the material through smoothing or other means.



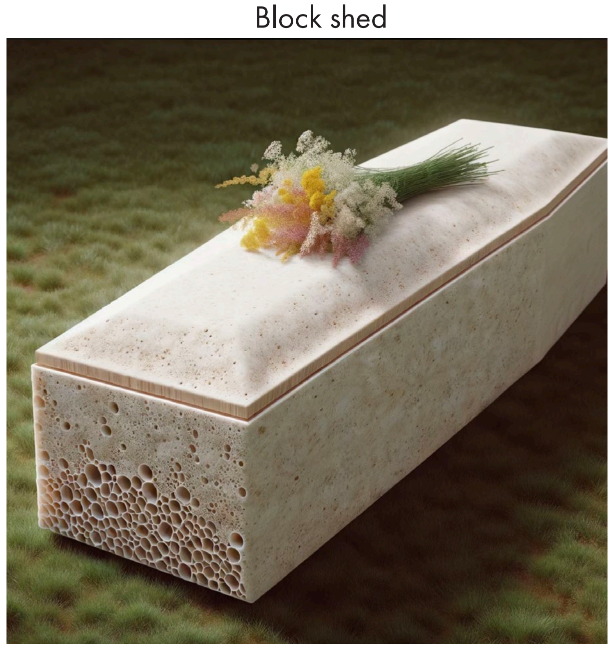
Modanloo et al, 2021

FUTURE IMAGINED

These images were generated using Chat GPT 4. They imagine how MBCs could be applied to the built environment and how these products could look. Mycelium offers an exciting means to create materials that can biodegrade when they are done being used. With the amount of construction waste in our landfills, we are in dire need of a more eco-friendly option. With further funding, research, and development of MBCs and other materials made from fungi, these materials have great potential to replace conventional construction materials, providing a sustainable alternative. Perhaps MBCs are further developed to be suitable for block construction of backyard sheds. Mycelium is already being 3D printed and concrete walls can be 3D printed, the next step is 3D printing a mycelium building. Mycelium has already been proven to be able to feed off of plastic, this should be pushed to create materials, where plastics are sequestered. And as mycelium leathers become more popular and cost effective to produce, they will increase in scale, leading to more home goods, such as translucent lamp shades and curtains, and architectural applications such as sun shading devices and architectural fabrics. Maybe one day, we will all be buried in mycelium caskets, and return to the earth with the material.

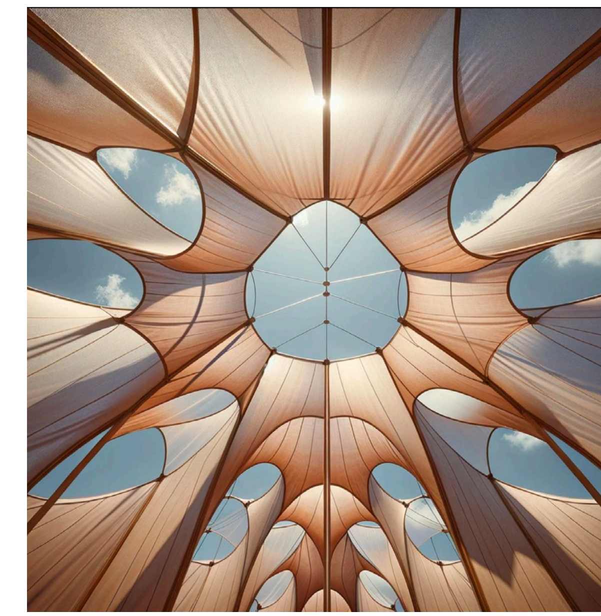

Block shed

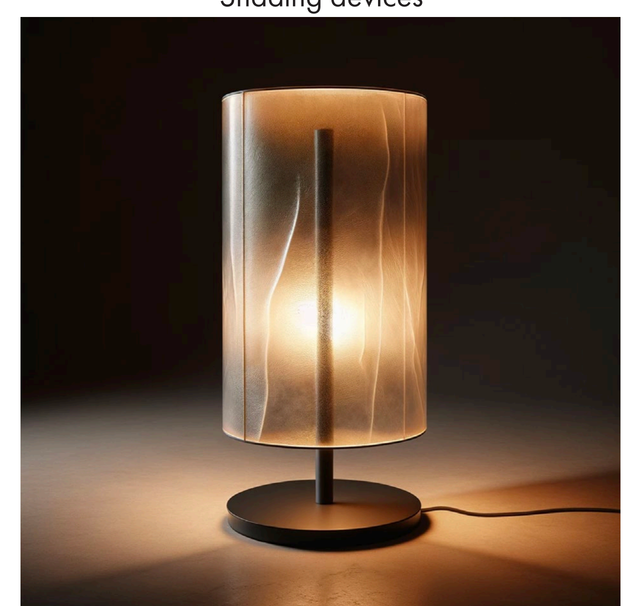

3D printed pavilion

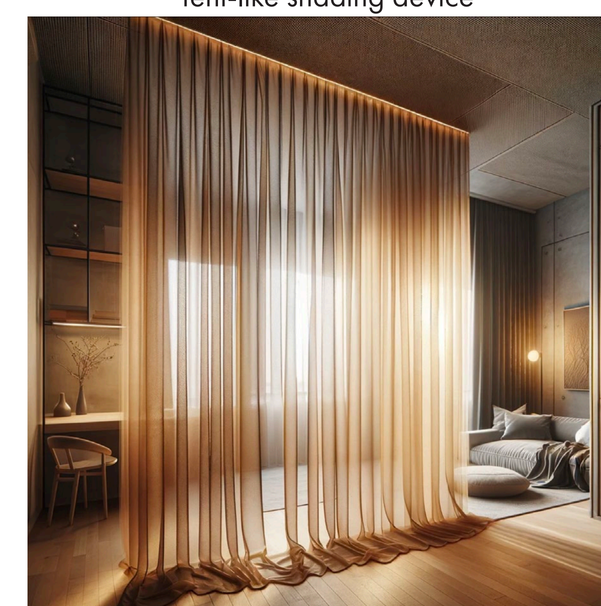

Compostable casket


Mycelium & plastic chair


Shading devices


Tent-like shading device


Lamp shade


Translucent curtains


Volodymyr Tokar / Unsplash

PART TWO
HOW TO GROW

Christopher Cassidy / Unsplash

Methodology

LITERATURE REVIEW

While this literature review focuses on research within the context of architecture and structural design, most of the research on mycelium-based composites is generated from other fields. The reviewed literature falls within the fields of mycology, biology, industrial design, architecture, and engineering. It explores topics such as mycoremediation, compressive and tensile strength of mycelium, best species and substrates for mycelium growth, 3D printing, bio-welding, mold making, and temporary structures made from MBCs.

While the majority of this research is pulled from published, peer-reviewed articles, amateur knowledge should not be discounted. Online forums, videos, and blogs contain a lot of great information posted by home growers. Many of these home-growers have been refining their process for years and have valuable insight. These platforms provide a space for home-growers to share recipes, diagnose contaminants, and troubleshoot issues with their setup. However, students should be critical when reviewing such information, because these forums can also host contradictory information and bad advice from inexperienced growers.

Research on MBCs within the field of architecture and construction is still very young. Most of the research explores MBCs at the scale of material samples, as it is a necessary step to perfect the material before designing a product or building a structure with it. Researchers within the fields of architecture and engineering are investigating many different ways of manipulating MBCs to optimize their strength and durability.

EXPERIMENTS

This research was also heavily informed by experiments in growing. This research tested different substrates, growing conditions, form work, and incubation times to learn what worked and what methods were easy. The experiments also worked to push the boundary of how low-tech a setup could be, for example using baking pans as form work and an Instant-pot instead of an autoclave. Experiments also provided opportunity to learn from mistakes and failures. The growth of mold and contaminants introduced valuable lessons in maintaining a clean environment, proper tool use, and air circulation.

INTERVIEWS

Through this research, there was collaboration and correspondence with another thesis student, Sira Udomritthiruj, who studied the potential use of MBCs as furniture. As a part of this research, a set of interviews were conducted to document Sira's knowledge, experience, and tips. These interviews were also provided to Sira for him to use as supplemental documentation in his own thesis. Collaborating with another thesis student resulted in stimulating discussions about the field, exchange of information, troubleshooting, peer-review, and sharing of materials.

Species and Substrate

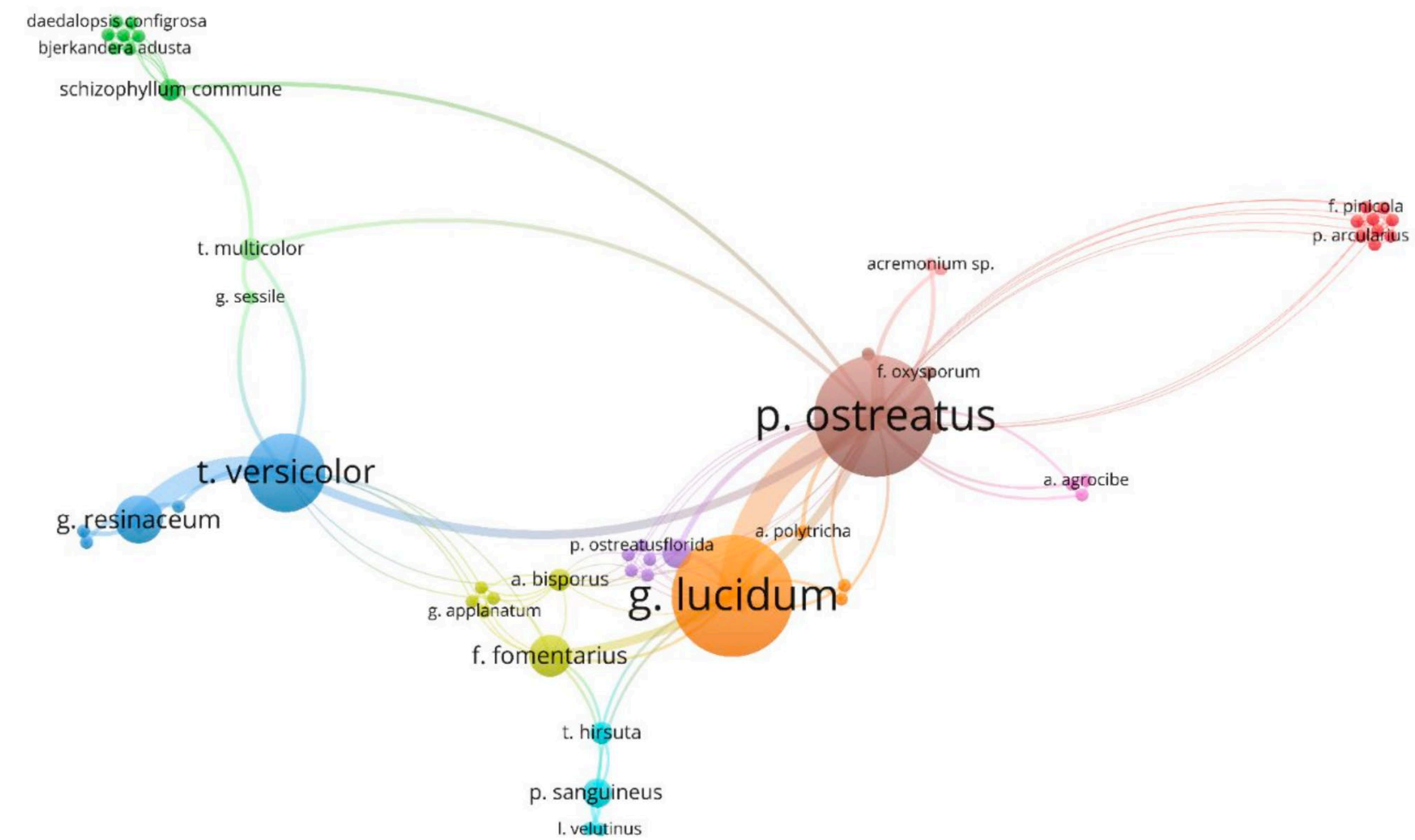
SPECIES OF FUNGI

Many research papers which investigate the species for growing MBCs do not actually name the species, because they consider that proprietary information. These papers will simply mention that the species belongs to the phylum Basidiomycota. This is incredibly unhelpful information, as there are over 31,000 species within the phylum Basidiomycota.

Many research teams choose to share their findings and contribute to the advancement of material research. One such team is Sydor et al. This research team conducted a review of 100 articles published between 2012 and 2022 to identify the most commonly used species. To identify the top contenders, they have generated a list of 11 characteristics that create a more effective MBC. These Characteristics include: "rapid hyphae growth, high virulence, dimitic or trimitic hyphal system, white rot decay type, high versatility in nutrition, high tolerance to a substrate, environmental parameters, susceptibility to readily controlled factors, easy to deactivate, saprophytic, non-mycotoxic, and capability to biosynthesize natural active substances". Among the nearly 100 publications, the most commonly used species are Pleurotus ostreatus (mentioned in 22 documents) and Ganoderma lucidum (mentioned in 20 documents). The third most common was Trametes versicolor (10 times). Sydor et al. note that all three of these species cause white rot. They include a diagram to show the most commonly mentioned species.

Pleurotus ostreatus and Ganoderma lucidum were also identified as the most successful species by Alemu et al. in their review titled, Mycelium Based Composite: The Future Sustainable Biomaterial. They explain that "these species have thick mycelium, grow easily on the locally available substrate, and have high ability of cellulose degradation".

The most commonly selected species all share something in common: they are all typically found growing on the sides of dead or decaying tree trunks. These species are all considered "white rot fungi" (Sydor et al, p. 12). An article titled, Engineered Mycelium Composite Construction Materials from Fungal Biorefineries: A Critical Review explains that these species are known as "white rot fungi", explaining that "since most mycelium composites are grown on lignocellulosic agricultural by-products and wastes, typically lacking optimal fungal nutrients, such as easily utilizable simple sugars (e.g. fructose, glucose and sucrose), white rot fungi, which degrade both cellulose and lignin (e.g. Trametes, Ganoderma and Pleurotus genera, phylum Basidiomycota), are typically used" (Jones et al.).



Sydor et al

Mushroom Mountain
Oyster (Pleurotus Ostreatus)

Field and Forest
Reishi (Ganoderma Lucidum)

Mushroomexpert.com
Turkey Tail (Trametes Versicolor)

SUBSTRATE

Substrate selection is another factor that contributes to the success of an MBC. Substrate provides mycelium with nutrients, moisture, and structure. When selecting a substrate, there are multiple factors to consider that can affect the appearance and strength of the resulting composite such as type of plant matter, size and shape, color, and water capacity.

The most important factor is the substrate's nutrient content, as it will greatly impact the growth of mycelium. Because fungi degrade cellulose and lignin, it is important to select a lignocellulosic biomass. Lignin and cellulose are found in the cell walls of woody, fibrous plant matter. Cellulose is easy to break down, while lignin is much stiffer. White rot fungi are especially great at breaking lignin down into carbon to use as food and material to grow their bodies (U.S. Department of Energy, 2021).

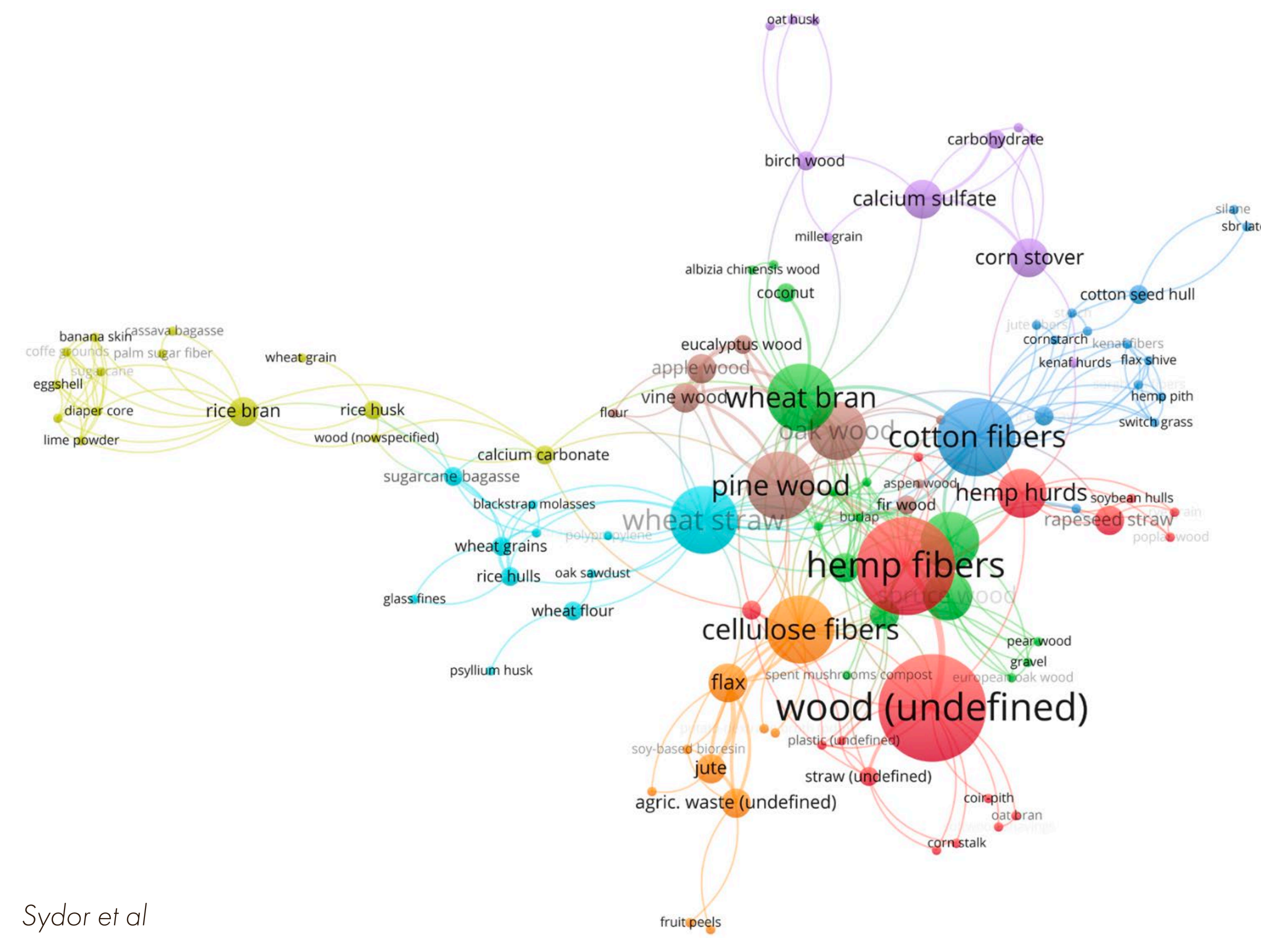
In the survey by Sydor et al, they found that all substrates used are lignocellulosic, but the best substrates contain enough nitrogen and carbohydrates to encourage quick mycelium growth (Sydor et al, p. 9). The most common wood substrate used is pine wood and the most common fibrous plants were hemp, cotton, and wheat straw.

The size and shape of the substrate can determine the strength of the substrate. Longer materials, like wood chips and straw, result in a stronger substrate (Sydor et al). This gives the mycelium more surface area to latch onto, and allows the individual pieces of substrate to become entangled.

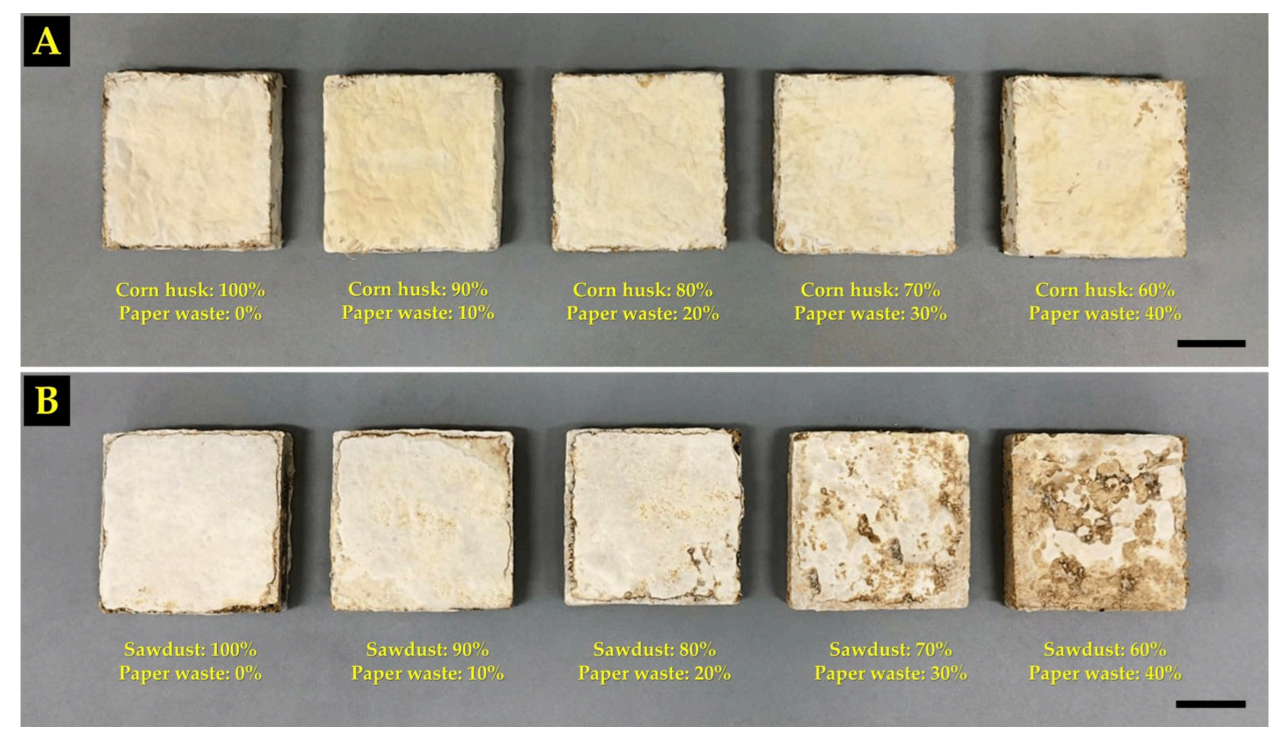
Substrate can be selected to impact the appearance of the resulting composite. Because the mycelium will not break all of the substrate down, much of it will still be visible after the composite is baked. Color and texture are factors to consider.

Substrate can also be sourced from agricultural waste. This is a great way to make MBC production a circular system. This way it would start with waste and in the end, the MBC could be composted. When collecting agricultural waste, one must be picky. It is important to know what type of plant matter is present in the waste. Collecting from a yard waste bin may not be a great option, because the substrate may come with wt leaves, soil, and matter that does not supply the fungi with proper nutrients.

In a study by Teeraphantuvat et al, a research team explored the addition of paper waste to MBCs. They compared MBCs made with corn husk, saw dust, and paper waste. They grew five samples with varying proportions of corn husk and paper waste, and five samples with varying proportions of sawdust and paper waste. Not only does this image show how different substrates can affect the appearance of the resulting sample, but they also studied the substrates' impact on material performance. They found that the adding paper waste significantly increased the MBC's material density, compressive strength. However, samples with added paper waste showed high water absorption and lower tensile strength than samples that only contained corn husk or sawdust.



Sydor et al



Improving the Physical and Mechanical Properties of Mycelium-Based Green Composites Using Paper Waste by Teeraphantuvat et al.

wheat straw

aspen wood chips

pine wood

hemp

cotton

agricultural waste

Process

OVERVIEW

The process of growing an MBC has four main phases: preparation of fungal spores, substrate preparation, assembly, and deactivation. When preparing fungal spores, there are four methods you can choose from. Depending on the method, you may start earlier or later in the process. For example, GIY kits will cover phases one and two, meaning all you will have to do is assembly and deactivation.

Each method will use both grain spawn and substrate, and you may wonder, "why can't I skip the grain spawn and start the mycelium on the final substrate? While the grain provides the best nutrients for the spores to develop into mycelium, it does not make the best substrate for a material. After the spores develop into mycelium while in the grain spawn, it is then introduced to a new substrate, like wheat straw, which better serves as scaffolding for a material.

After incubating the grain spawn until small tufts of white mycelium begins growing, it is then introduced to organic substrate. Substrate is selected for its ability to supply nutrients to the mycelium, for its appearance, and for its ability to stick together.

1. PREPARE FUNGAL SPORES

Spores come in four basic forms, ranging from most to least accessible: GIY kits, grain spawn, liquid culture, and spore prints. GIY Kits, grain spawn, and liquid culture can be purchased online, while spore prints are made by gathering spores from a mushroom.

Mycelium begins as a spore. Spores are first grown on grain, such as rye berries, until they develop into mycelium. This is called grain spawn. Regardless of which method you choose, grain spawn will typically be part of the process. You can choose to either buy pre-inoculated grain spawn or make your own.

GIY Kit

The most beginner friendly method is buying a Grow-It-Yourself (GIY) Kit online. You will be much more likely to end up with a successful MBC sample. This is also a great option if your project explores form and structure rather than the composition of the material itself. These kits come with pre-inoculated grain spawn and pre-sterilized substrate that the fungal spores are already proven to take to. All you have to do is combine the grain spawn and substrate, place in a mold, incubate, and bake!

Grain Spawn

If you want more control over the composition of the material and type of substrate, grain spawn is a great option. Grain spawn can be ordered online and you can choose from a variety of fungal species. It is delivered as a bag of grain, typically rye berries, that has been pre-inoculated with fungal spores.

Liquid Culture

Liquid culture is a more advanced option that gives you control over the type of grain and substrate. Liquid culture comes in the form of a syringe filled with spores in a liquid medium. You will also need to buy grain and micro filter bags. You will fill the bags with pre-sterilized grain (you can do this in a pressure cooker or instant pot) and then inject the bag with the liquid culture.

Spore Print

The most advanced method is getting your own spores. This can be done by getting a spore print from a mushroom or you can take a cutting of its stalk to propagate in an agar petri dish. This requires a good understanding of how to maintain a sterile environment along with additional materials such as an agar petri dish and scalpels.

After acquiring your choice of fungal spore, allow the spores to incubate until they start to develop into mycelium. Once there is evidence of mycelial growth, you can move onto the next phase where you will introduce the mycelium to substrate.

2. SUBSTRATE PREPARATION

Depending on which substrate you select, it may need to be processed. For example, a wood chipper can be used to make wood chips from sticks and logs. Small chips can be made using a rasp or sawdust can be produced through sanding. Longer substrates like wheat straw should be cut up into smaller pieces.

Substrate should then be soaked in water, because mycelium do well in a moist environment. The substrate should be added to jars with a few tablespoons of water.

Then, the substrate needs to be pasteurized. This step is vital in ensuring any bacteria or pathogens are killed, as these could prevent mycelium growth. The jars of substrate and water will be cooked in a pressure cooker or instant pot for 2-3 hours.

3. ASSEMBLY

After the substrate is pasteurized, allow it to cool before draining any excess water. Now the substrate can be mixed with the grain spawn.

Pack the substrate and grain spawn mixture into a pre-sterilized mold. You can either make your own mold or use something you already have, such as a glass tupperware, metal baking pan, or silicon ice cube tray. This mold will be covered and left in a martha tent or a space with good ventilation and limited foot traffic.

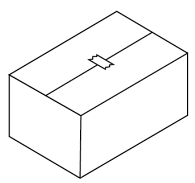
Monitor the sample everyday and check for contamination by looking for color changes or pungent smells. Allow the sample to grow until mycelium has grown evenly throughout the substrate, the sample will look white.

4. DEACTIVATION

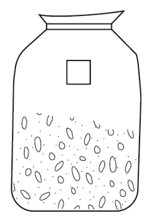
After the sample has demonstrated successful growth, it is time to remove it from its mold and stop mycelium growth through dehydrating the material. In a proper laboratory the deactivation process is typically done using a dehydrator, but an oven will accomplish the same results.

1. PREPARE FUNGAL SPORES

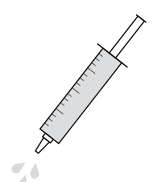
A. Select form of spore



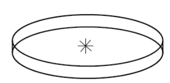
GIY Kit



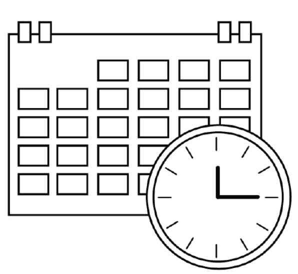
Grain Spawn



Liquid Culture

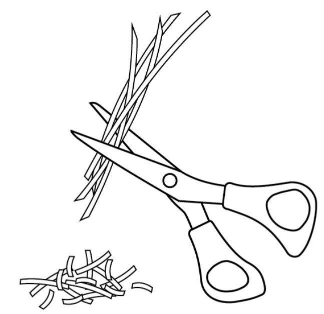


Spore

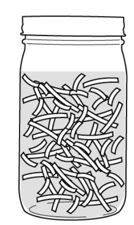


B. Incubate until mycelium begins to grow

2. SUBSTRATE PREPARATION



A. Shred substrate

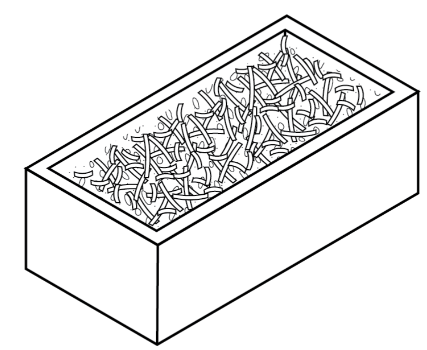


B. Soak substrate in water

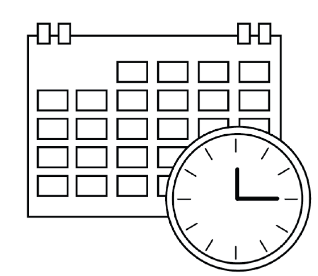
C. Pasteurize substrate and water in pressure cooker/instant pot

3. ASSEMBLY

A. Mix substrate and grain spawn

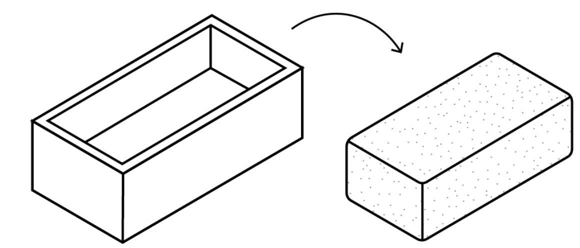


B. Mold packing

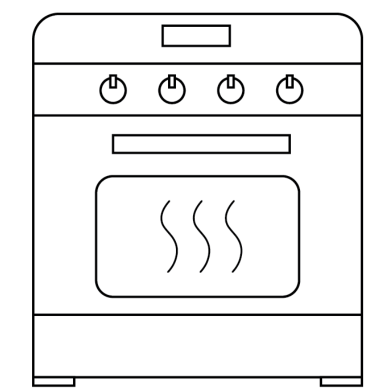


C. Incubate

4. DEACTIVATION



A. Remove from mold



B. Bake in the oven to halt mycelium growth

MOVEMENT DIAGRAM

A. Instant pot
B. Jars with lids
C. Bowl of straw substrate
D. Latex gloves
E. Alcohol
F. Hand Soap
G. Measuring cup
H. Spoon (to stir substrate and grain spawn
I. Knife (to puncture plastic wrap)
J. Scissors (to shred substrate)
K. Plastic wrap (to cover molds)
L. Molds
M. Grain Spawn

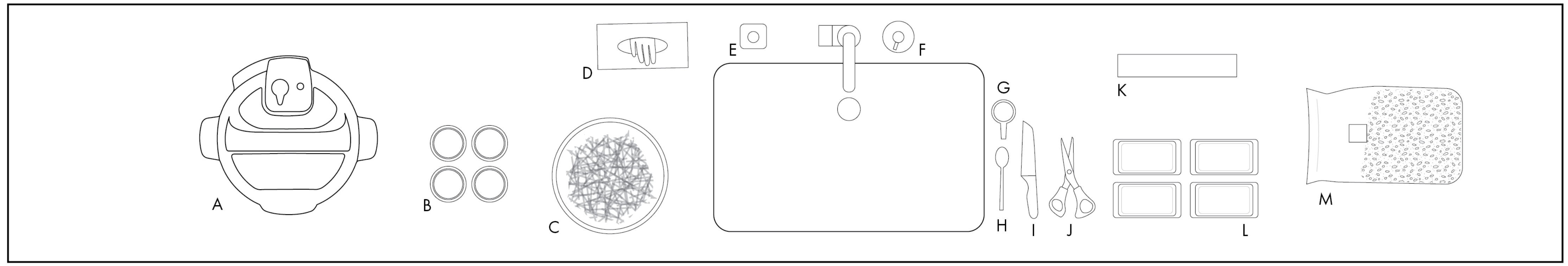
Inspired by Sarah Wigglesworth's "Disordered Dining", this illustration shows the movement and disorganization that occurs during the substrate preparation and assembly phases of the process.

The kitchen counter top begins with neatly organized tools, equipment, and consumables. During preparation, things are spilled and moved around, and washed or re-sterilized.

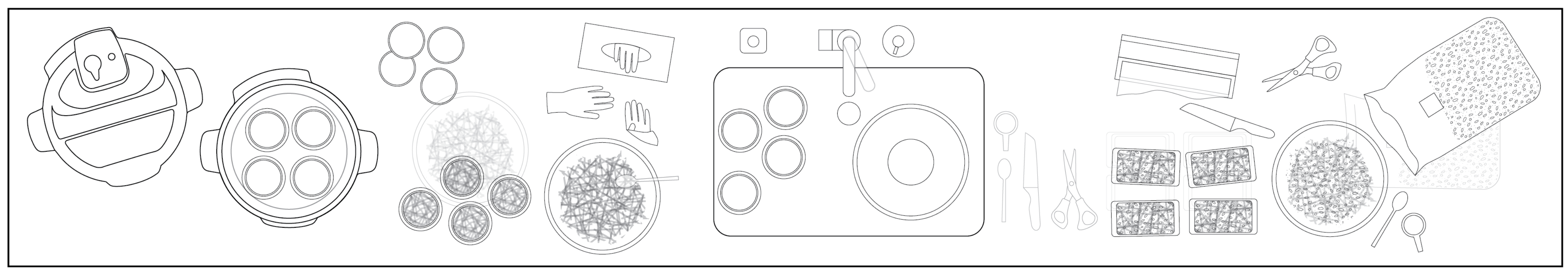
When working with mycelium, it is important to maintain a clean workspace, wear PPE, and limit movements. Sterilizing tools and equipment kills contaminants that live on surfaces. Wearing latex gloves and a mask helps stop germs from dirty hands and breathing. Limiting movements will reduce the chance of cross-contamination.

After the substrate is combined with the grain spawn and packed into molds, the lab is left with a sink full of dirty dishes and four neatly wrapped samples ready to grow!

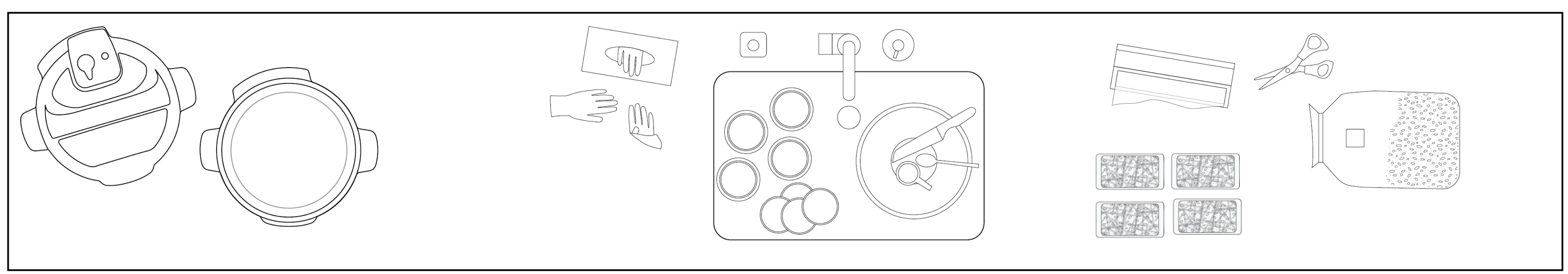
Before



During



After



Lab Design

CBE INSPIRE FUND GRANT

Inspire Fund is designed to support research activities within the college. Our grant proposal was to design and construct a CBE Mycelium Grow Lab for student-led research. Student research will contribute to a growing body of CBE knowledge on mycelium cultivation and material production. The research team consists of Gundula Proksch as PI, Bella Batson as Co-PI and Tyler Sprague and Sira Udomritthiruj as a consultant team.

LAB DESIGN

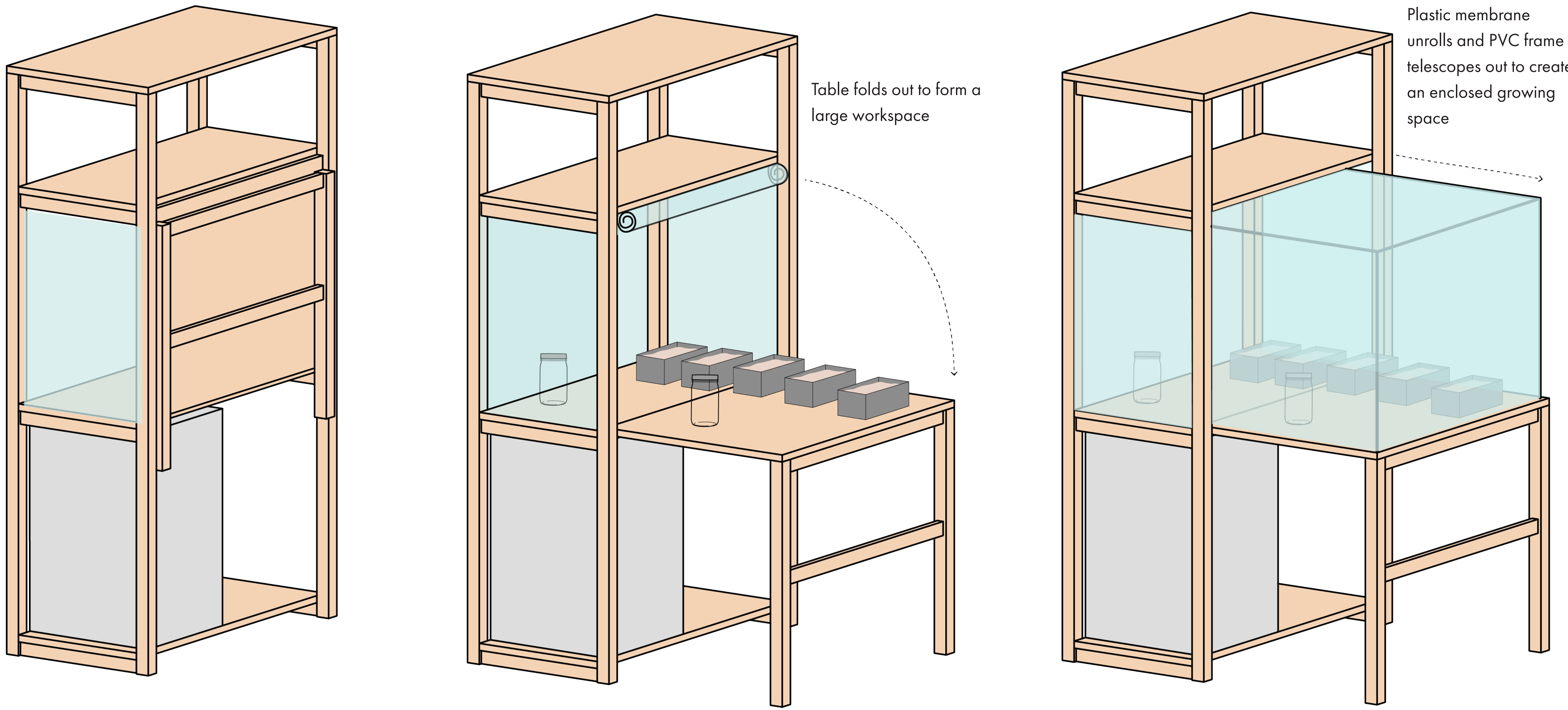
The student lab should be a structure that can fold out to create a grow space, and be able to collapse to provide storage for equipment when not in use. This infrastructure should provide tabletop space to grow mycelium and prepare substrates, shelving for a mini fridge and equipment, a membrane to cover the grow space, and nearby outlets to plug equipment in.

BUDGET

The budget follows that awarded by the CBE Inspire fund, between $4000 and $5000. The table to the right outlines equipment and tools necessary to conduct experiments, along with the cost of consumable products such as spores, tape, foil, and PPE. The budget also has room for larger equipment like a microscope, which students could use to look at spores, substrate, and their final materials.

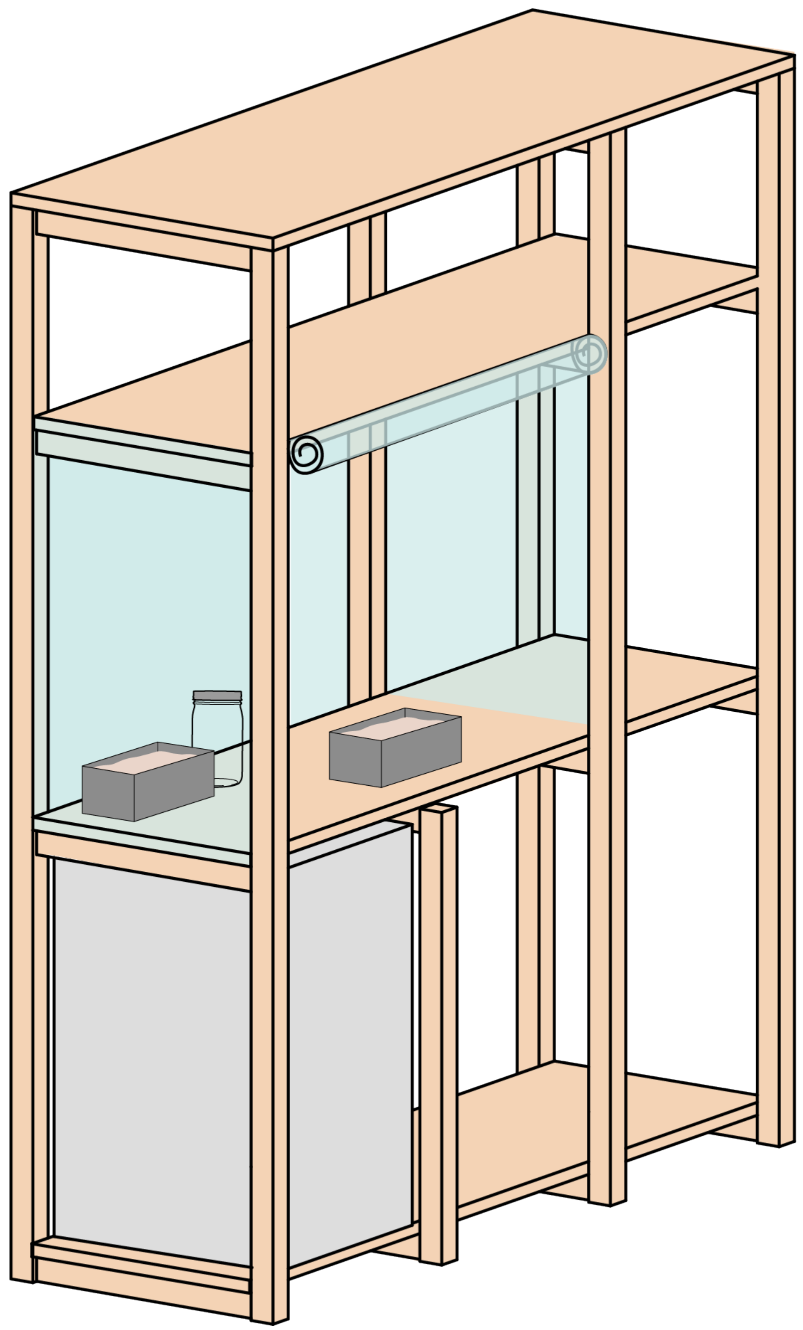
Lab Structure and Storage	
Shelf like structure that includes structural material (wood)	$400
Membrane enclosure which expands into a grow space during active experiments and contracts to store the grow equipment when not in use	$800
Hardware	$200
Storage bins and small containers	$350
	$1,750
Growing Equipment	
Pressure cooker (2x $75)	$150
Jars with microbe filter lids	$100
Scalpels	$50
Molds	$50
Containers	$50
Hygrometer	$30
Temperature gauge	$20
Microscope	$800
Vertical compression test equipment	$400
	$1,650
Consumables	
Grain spawn ($40 x 5)	$200
Pre-made Liquid culture ($20 x 20)	$400
Substrate	$50
Spawn bags	$20
Aluminum foil, tape, cleaning supplies	$50
	$720
	Total $4,120

LAB DESIGN 1

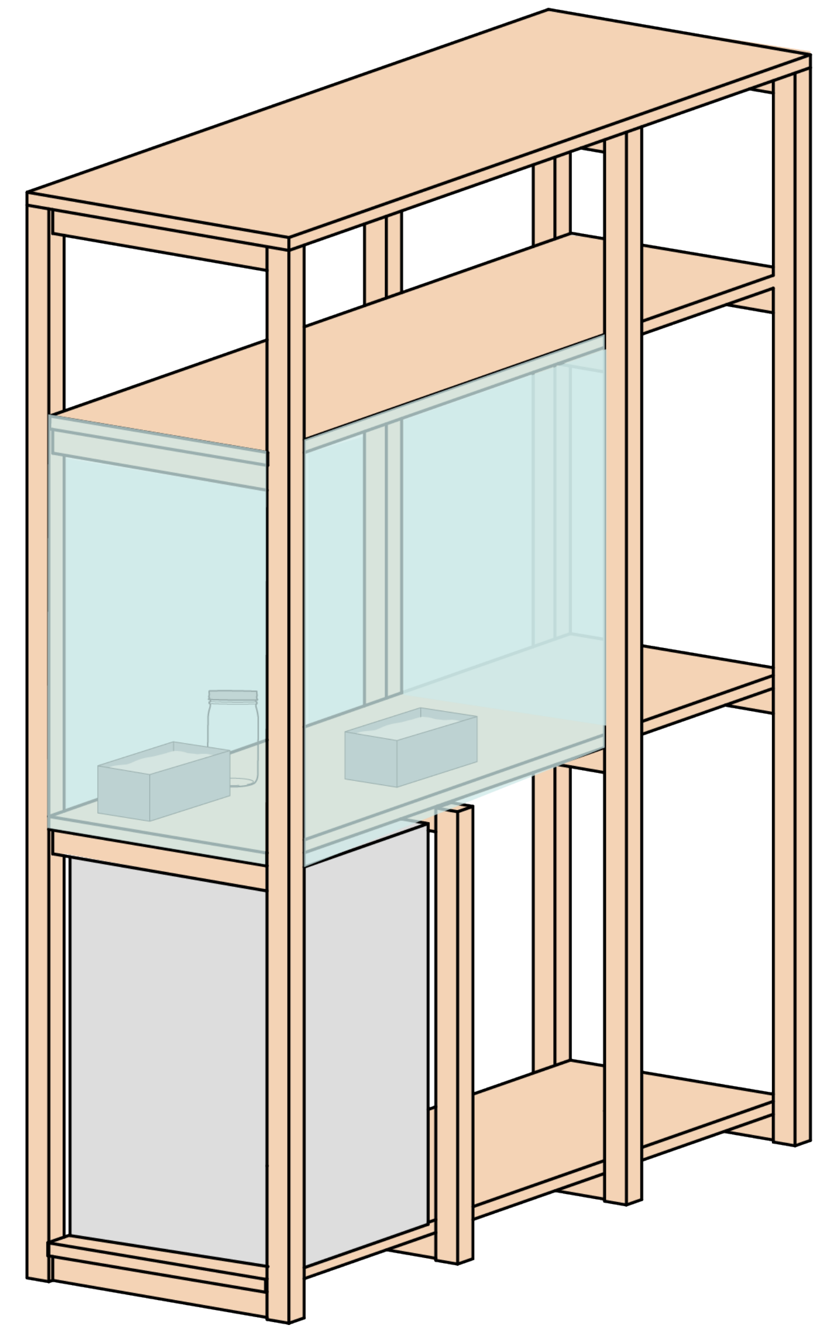


closed mode   open mode   grow mode

LAB DESIGN 2



open mode



grow mode

Recipes

The following pages contain recipes which students can use to grow their own mycelium materials. Recipe 1 was developed as a product of this research, while the other recipes are sourced from other theses projects or guides. The referenced recipes have been adapted to suit a low-tech student lab setup and formatted to include additional tips and tricks.

Mycoworks
MBC material samples.

RECIPE 1

Straw + Woodchip MBC

Before introducing the grain spawn to the substrate, allow the grain spawn to grow on its own for about a week, until there is visible mycelium growth. Be sure to use multiple molds and pans to create distance between samples in order to prevent contamination.

MATERIALS

- Tap water
- 4 mason jars (16 oz)
- Gloves
- Alcohol
- Spoon
- Small kitchen knife
- Silicon molds or small metal loaf pans
- 2 large bowls
- Plastic wrap
- Grain spawn
- 4 lb bag of Pleurotus ostreatus grain spawn from Field and Forest Products
- Wheat straw (I bought a large bag for $5.99 from Bothell Feed Center)
- Aspen wood chips (I bought a bag of "natural aspen small animal bedding" from the brand Sophresh at Petco for $11.99)

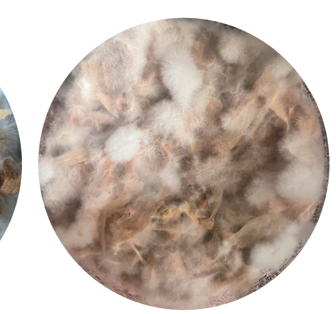
EQUIPMENT

- Pressure cooker/Instant pot
- Oven

PROCEDURE

1. Allow grain spawn to grow in bag for one week until white mycelium begins to form
2. Prepare substrate
3. Using clean scissors, cut wheat straw into 1"- 2" lengths.
4. Fill 2 jars with aspen chips and cup water, and the other two jars with the cut wheat straw and cup water.
5. Place all four jars inside the Instant Pot with the metal trivet underneath.
6. Add 2 cups of water to the Instant Pot and put the lid on.
7. Start the pressure cook cycle for two hours and turn off the "keep warm" button. Leave the venting knob in the vent position. As the Instant Pot begins to heat up and build pressure, it will begin to release steam. Allow the Instant Pot to vent for 10 minutes before turning the knob to the closed setting. Leave the Instant Pot alone for the remaining time.
8. After 2 hours, Remove jars from Instant Pot.
9. Sterilize the molds, spoon, and knife by wiping them down with alcohol. Allow them to dry.
10. Pressure will have created a seal around the jar lids. Use the spoon to carefully pry the lid off of each jar.
11. Wearing gloves, drain the excess water from each jar.
12. Empty the wheat straw and aspen chips into two separate clean bowls. *Because the Aspen chips did not feel very saturated with water, I added ¼ cup of water to their bowl and mixed it up.
13. Add 1½ cups of the grain spawn to each bowl of substrate. Mix with gloved hands, evenly distributing the grain spawn.
14. Prepare molds
15. Fill the molds with the mixtures, making sure to keep the aspen chip mixture separate from the wheat straw mixture. Fill each mold to the top so there is no space.
16. Cover each mold with two pieces of plastic wrap.
17. Using a knife, cut two slits in the plastic wrap on each mold.
18. I placed the two metal molds outside, loosely covered with a tupperware so they are sheltered from rain but can still get air flow. I placed the remaining molds in my garage, where there is low traffic.
19. To prevent mold growing due to still air, I "burped" each mold once every other day. This just means uncovering and recovering it for a few seconds for air change.
20. Allow samples to grow for two weeks. Check on samples each day to monitor healthy growth. Look for any discoloration or pungent smells. Mycelium should be white, not gray.
21. After substantial mycelium growth, gently remove samples from molds.
22. Place samples on a baking sheet and bake in the oven for 2 hours at 200° F

6 days of growth



10 days of growth

RECIPE 2

Elsacker's MBC

Recipe adapted from *A comprehensive framework for the production of mycelium-based lignocellulosic composites* by Elise Elsacker et al.

In this study, researchers surveyed research on MBC growth and tested different substrates, methods of substrate preparation, fungal species, incubation times, and post-processing methods. With Tramates versicolor, they explored substrates including flax dust, flax long fibers, flax waste, wheat straw dust, wheat straw, hemp fibres and pine softwood shavings. The substrate fibers will be 20% of the sample's weight, sterile demineralised H2O will be 70%, and mycelium spawn will be 10%.

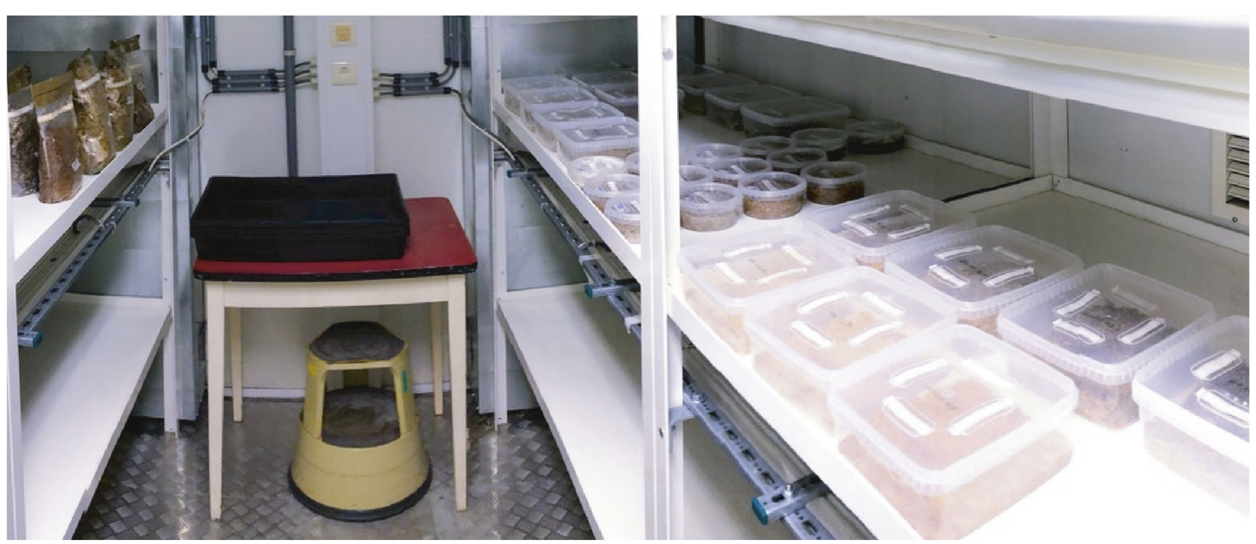
MATERIALS

- Tramates versicolor grain spawn
- Choice of substrate: Flax dust, flax long fibers, flax waste, wheat straw dust, wheat straw, hemp fibres, pine softwood shavings, or a combination
- Mold (The referenced article used PVC molds, but metal or glass is just as good)
- Glass jar with metal lid (Mason jar or

EQUIPMENT

- Pressure cooker/Instant pot
- Oven
- Incubator (If you cannot incubate the mycelium at 82°F, you can just give it more time to grow at room temperature)

Samples drying



Growth chamber setup with grain spawn on the right and containers of MBC sampels on the left

PROCEDURE

1. Allow grain spawn to incubate in the bag for approximately 5 days, or until mycelium is visible.
2. Soak substrate in water for 24 hours, then rinse abundantly, and blend
3. Fill jars with substrate and add about 1/3 cup water (enough to steam the substrate).
4. Place all four jars inside the Instant Pot with the metal trivet underneath, add 2 cups of water to the Instant Pot and put the lid on.
5. Pasteurize substrate in the pressure cooker at approximately 100°C (212°F) for 100min. Start the pressure cook cycle for two hours and turn off the "keep warm" button. Leave the venting knob in the vent position. As the Instant Pot begins to heat up and build pressure, it will begin to release steam. Allow the Instant Pot to vent for 10 minutes before turning the knob to the closed setting. Leave the Instant Pot alone for the remaining time.
6. After 100min, the Instant Pot should turn off by itself. Allow jars to cool before removing from Instant Pot.
7. Pressure will have created a seal around the jar lids. Use a clean spoon to carefully pry the lid off of each jar.
8. Wearing gloves, drain the excess water from each jar.
9. Sterilize mold and equipment using 70% rubbing alcohol.
10. Add grain spawn to the substrate. The amount of grain spawn depends on the weight of the wet substrate. The final sample's weight should be 90% wet substrate and 10% grainspawn.
11. Pack mixture into molds in layers and compress with a spoon before adding a new layer. More compact fibers with less air space will result in a stronger composite.
12. Incubate molds for 8 days at 28°C (82°F). If you do not have the means to maintain these conditions and must incubate at a cooler temperature, allow samples to incubate for more time.
13. Remove samples from their molds to allow homogeneous colonization on the sides that were previously in contact with the mold. Allow samples to grow for an additional 8 days.
14. In a convection oven, dry samples at 60°C-125°C (140°F-257°F) for 2 hours or until moisture has evaporated from the sample. (Temperatures vary because multiple studies cited in this article recommended different temperatures. I recommend 200°F)

Fully grown sample pre-baking

RECIPE 3

Grow with a GIY Kit

Recipe adapted from *5 Step Grow It Yourself Manual* by GROWN bio.
This manual was produced by the Dutch company GROWN bio as instructions for the GIY kits they sell on their website (https://www.grown.bio/product/giy-kit/). GIY kits can also be purchased from U.S. sites like Liquid Fungi or Northspore. This is an easy, all-in-one option that allows for more experimentation with form work.

MATERIALS

- GIY Kit
- Ethanol
- Plastic wrap
- Scissors
- Gloves
- Flour (30g per 1 kg substrate)
- Growth form
- Large bowl
- Kitchen scale

EQUIPMENT

- Oven

GIY Kit

Substrate and flour preparation

Mold packing

PROCEDURE

Preparation

1. Wearing gloves, clean all utensils and surfaces using ethanol.
2. Add the pre-inoculated substrate to a bowl and add flour (30g per 1kg substrate)
3. Break the substrate up using gloved hands and mix thoroughly with the flour. Be sure to crumble any lumps.

Fill the Growth Form

4. Choose or make a form.
5. Clean the form with ethanol.
6. Fill form completely with the pre-inoculated substrate and flour mixture.
7. Cover the top of the form container with plastic wrap.
8. Cut small holes every 3cm in the plastic wrap to allow for air flow.

Growing Phase 1

9. Let the project grow for about 4-5 days at 22°C-26°C (72°F-79°F).If this temperature cannot be achieved, allow the sample to grow for longer, it could even take more than 7 days.

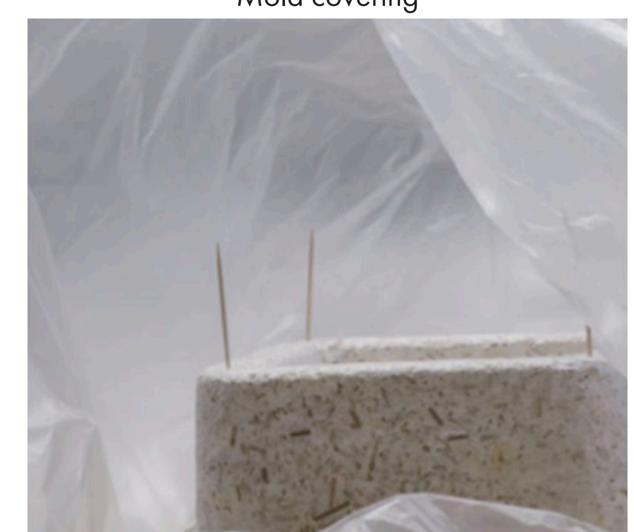
Popping and Growing phase 2

10. Pop the sample out of the form work by flipping the form upside down and tapping on the bottom.
11. Allow the sample to grow for 2 more days outside of the mold at the same temperature. Place sample in an enclosed pod such as a martha tent or even a plastic bag. There should be enough space, the sample should not be in contact with surrounding walls. After two days (or more if air temperature is cooler), the sample should grow a white outer skin.

Dry

12. For products less than 2.5cm thick, place the product in the oven at +/-40°C (104°F) for 3-4 hours. Leave the oven door open a crack to allow moisture to escape.
    For products more than 2.5cm thick, place the product in the oven at 70°C (158°F) for 2-3 hours.
    To know if the product has properly dried, "the best test is to measure the weight before and after. Mycelium substrate contains approximately 60% moisture, so the product should lose 50-60% of its initial weight" (GROWN bio).

Mold covering



Growing phase 2

RECIPE 4

Mycelium Leather

Recipe adapted from *The Purhyphae Project* by Annah-Olade Sangosanya

For her thesis at the Fabricademy of Barcelona, Sangosanya developed a process for growing and treating mycelium leather. She first grows mycelium on agar from liquid culture. Instead of substrate, the mycelium grows on a liquid mixture of malt and yeast. After growing into a soft disc, the mycelium is dehydrated, heat pressed, and coated in beeswax. The result is a translucent, flexible leather! Sangosanya's process calls for specific equipment such as a heat press, dehydrator, and incubator. This recipe has been adapted to accommodate a low-tech set up.

MATERIALS

- Parchment paper
- Micropore tape (available at a pharmacy)
- Glass jar with metal lid (Mason jar or recycled pasta sauce jar)
- Aluminum foil
- Hammer
- Drill
- Lighter
- Beaker or liquid measuring cup
- Ethanol
- Scalpel
- Oyster or Reishi mycelium on agar
- 300 mL distilled water
- Beeswax
- 4g malt extract*
- 2g yeast extract*

*If you do not have malt and yeast, they can be substituted for 6g honey

EQUIPMENT

- Pressure cooker/Instant pot
- Dehydrator (An oven will work fine)
- Heat Press (You can substitute this with an iron or even a hair straightener)
- Incubator (If you cannot incubate the mycelium at 80F, you can just give it more time to grow at room temperature)


Before heat pressing


After heat pressing


After beeswax coating

PROCEDURE

1. Drill a 5mm hole in the lid of the jar and smooth the edges with a hammer
2. Tape the hole with two layers of micropore tape on each side
3. In the jar, add 4g malt extract, 2g yeast extract, and 300mL distilled water. The malt and yeast can also be substituted for 6g honey.
4. Place the lid on the jar and cover it with aluminum foil to prevent the filter from getting wet.
5. Sterilize the jar and contents in the pressure cooker for 1 hour.
6. Allow the jar to cool to room temperature.
7. Prepare a workspace by spraying it down with ethanol.
8. Sterilize a scalpel using a flame.
9. Cut a piece of mycelium from the petri dish. It should be roughly 1 cm2
10. Place the piece of mycelium in malt mixture in the jar.
11. Put the lid back on the jar and cover with aluminum foil. Incubate the jar at around 80F for roughly 30 days, or until mycelium grows thick. If you do not have
12. Observe over the 30 days to make sure mycelium is growing and uncontaminated. Healthy growth should start "growing submerged and fluffy and then start pointing towards the oxygen and finally colonizing the entire top of the liquid surface, leading to a liquid state surface fermentation"().
13. When the mycelium is approximately 2cm thick, remove it from the jar. It should look like a spongey disk.
14. Place the mycelium sample between two pieces of parchment paper and heat press at 300F for 20 seconds. Wipe excess water away with tissue paper.
15. Prepare a 30% glycerol bath by mixing 150 mL glycerol and 250 mL water
16. Soak the heat pressed mycelium sample in the bath overnight. This will help plasticize the material.
17. After removing the mycelium sample from the bath, pat dry.
18. Dry the sample in the dehydrator at 95 F for 8 hours.
19. Apply melted beeswax to the surface of the mycelium sample with a brush.
20. If needed, put the sample back through 1-3 more cycles in the heat press at 300F for 20 seconds to make the beeswax uniform.


Mycelium ready to harvest from liquid malt

Brushing beeswax on mycelium leather sample

Bibliography

Alemu, D., Tafesse, M., & Mondal, A. K. (2022). Mycelium-Based Composite: The Future Sustainable Biomaterial. International Journal of Biomaterials, 2022, 1–12. https://doi.org/10.1155/2022/8401528

Ascomycetes—An overview | ScienceDirect Topics. Retrieved April 19, 2024, from https://www.sciencedirect.com/topics/biochemistry-genetics-and-molecular-biology/ascomycetes

Attias, N., Danai, O., Abitbol, T., Tarazi, E., Ezov, N., Pereman, I., & Grobman, Y. J. (2020). Mycelium bio-composites in industrial design and architecture: Comparative review and experimental analysis. Journal of Cleaner Production, 246, 119037. https://doi.org/10.1016/j.jclepro.2019.119037

Biohm Limited. Mycelium Tech. BIOHM. Retrieved June 18, 2024, from https://www.biohm.co.uk/mycelium

Boddy, L., Frankland, J., & West, P. van. (2007). Ecology of Saprotrophic Basidiomycetes. Elsevier.

Biology 2e, Biological Diversity, Fungi, Classifications of Fungi. OpenEd CUNY. Retrieved April 19, 2024, from https://opened.cuny.edu/courseware/lesson/725/overview

Chandra, M., Kohn, C., Pawlitz, J., & Powell, G. (2016). Real cost of styrofoam. St. Louis University.

Dessi-Olive, J. (2019). Monolithic Mycelium: Growing Vault Structures. Construction Materials.

Dessi-Olive, J. (2022). Strategies for Growing Large-Scale Mycelium Structures. Biomimetics, 7(3), Article 3. https://doi.org/10.3390/biomimetics7030129

Doughton, S. (2023, November 17). Seattle, king county initiatives build a better approach to construction waste. The Seattle Times. Retrieved from https://www.seattletimes.com/pacific-nw-magazine/seattle-king-county-initiatives-build-a-better-approach-to-construction-waste/.

Elsacker, E., Vandelook, S., Van Wylick, A., Ruytinx, J., De Laet, L., & Peeters, E. (2020). A comprehensive framework for the production of mycelium-based lignocellulosic composites. Science of The Total Environment, 725, 138431.

Elsacker, E., Vandelook, S., Brancart, J., Peeters, E., & De Laet, L. (2019). Mechanical, physical and chemical characterisation of mycelium-based composites with different types of lignocellulosic substrates. PLoS One, 14(7), e0213954.

EPA. (2018). Advancing Sustainable Materials Management: 2018 Fact Sheet. Washington DC: United States Environmental Protection Agency. Retrieved from https://www.epa.gov/sites/default/files/2021-01/documents/2018_ff_fact_sheet_dec_2020_fnl_508.pdf

GROWN bio. 5 step Grow it Yourself manual. https://www.grown.bio/wp-content/uploads/2023/06/grown_bio_grow_it_yourself_manual_23.pdf?v=796834e7a283

Imhof, B., & Gruber, P. (2015). Built to Grow—Blending Architecture and Biology. Walter de Gruyter GmbH. http://ebookcentral.proquest.com/lib/washington/detail.action?docID=4338523

Jones, M., Mautner, A., Luenco, S., Bismarck, A., & John, S. (2020). Engineered mycelium composite construction materials from fungal biorefineries: A critical review. Materials & Design, 187, 108397. https://doi.org/10.1016/j.matdes.2019.108397

Katharina Unger & Julia Kaisinger. FUNGI MUTARIUM. LIVIN Studio. Retrieved April 21, 2024, from http://www.livinstudio.com/fungi-mutarium

Low, L. (2023, April 14). Fungi makes meal of hard-to-recycle plastic. The University of Sydney. Retrieved June 20, 2024, from https://www.sydney.edu.au/news-opinion/news/2023/04/14/fungi-makes-meal-of-hard-to-recycle-plastic.html

Lurie-Luke, E. (2014). Product and technology innovation: What can biomimicry inspire?. Biotechnology advances, 32(8), 1494-1505.

Luz, J. M. R. da, Paes, S. A., Nunes, M. D., Silva, M. de C. S. da, & Kasuya, M. C. M. (2013). Degradation of Oxo-Biodegradable Plastic by Pleurotus ostreatus. PLOS ONE, 8(8), e69386. https://doi.org/10.1371/journal.pone.0069386

Maloney, R. (2014, June 25). Hy-Fi reinvents the brick. ARUP. https://www.arup.com/en/news-and-events/hyfi-reinvents-the-brick

Modanloo, B., Ghazvinian, A., Matini, M., & Andaroodi, E. (2021). Tilted Arch; Implementation of Additive Manufacturing and Bio-Welding of Mycelium-Based Composites. Biomimetics, 6(4), Article 4. https://doi.org/10.3390/biomimetics6040068

Mogu. Mogu Acoustic. Retrieved June 18, 2024, from https://mogu.bio/acoustic-collection/

MycoWorks. (2024, January 31). Ligne Roset commits to procure a portion of ReishiTM production capacity. MycoWorks. https://www.mycoworks.com/ligne-roset-announces-new-commitment

okom wrks Labs. Structural Mycelium. Retrieved June 18, 2024, from https://www.okomwrks.co/structural-mycelium#this-changes-everything

Samat, A. F., Carter, D., & Abbas, A. (2023). Biodeterioration of pre-treated polypropylene by Aspergillus terreus and Engyodontium album. Npj Materials Degradation, 7(1), 1–11. https://doi.org/10.1038/s41529-023-00342-9

Sangosanya, A.-O. (2022). Purehyphae. https://class.textile-academy.org/2022/annah-sangosanya/FinalProject/08_FinalOutcome/

Srubar III, W. V. (2022). Engineered Living Materials. Springer Nature.

Srubar, W. V. (2021). Engineered Living Materials: Taxonomies and Emerging Trends. Trends in Biotechnology, 39(6), 574–583. https://doi.org/10.1016/j.tibtech.2020.10.009

Sun, W., Tajvidi, M., Howell, C., & Hunt, C. G. (2022). Insight into mycelium-lignocellulosic bio-composites: Essential factors and properties. Composites Part A: Applied Science and Manufacturing, 161, 107125.

Sydor, M., Cofta, G., Doczekalska, B., & Bonenberg, A. (2022). Fungi in Mycelium-Based Composites: Usage and Recommendations. Materials, 15(18), 6283. https://doi.org/10.3390/ma15186283

Teeraphantuvat, T., Jatuwong, K., Jinanukul, P., Thamjaree, W., Lumyong, S., & Aiduang, W. (2024). Improving the physical and mechanical properties of mycelium-based green composites using paper waste. Polymers, 16(2), 262.

U.S. Department of Energy (2021, April 29). Hungry Fungi: White-Rot Fungi Eat All Components of the Wood They Decompose. Biological and Environmental Research. Retrieved June 18, 2024, from https://www.energy.gov/science/ber/articles/hungry-fungi-white-rot-fungi-eat-all-components-wood-they-decompose#:~:text=The%20Science,ability%20to%20break%20down%20lignin.

Van Wylick, A., Rahier, H., De Laet, L., & Peeters, E. (2024). Conditions for CaCO3 Biomineralization by Trichoderma Reesei with the Perspective of Developing Fungi-Mediated Self-Healing Concrete. Global Challenges, 8(1), 2300160. https://doi.org/10.1002/gch2.202300160

Wilson, A. (2024, January 1). Greensulate – A fungus-based insulation material that's grown rather than manufactured. Building Green. Retrieved June 18, 2024, from https://www.buildinggreen.com/blog/greensulate---fungus-based-insulation-material-thats-grown-rather-manufactured

Why the Built Environment. (2023). Architecture 2030. https://www.architecture2030.org/why-the-built-environment/#:~:text=Of%20those%20total%20emissions%2C%20building,for%20an%20additional%2015%25%20annually.

Appendix

INTERVIEW 1

Interview with Sira Udomritthiruj
Date: March 25, 2024
Duration: 39 minutes

Bella: Please introduce yourself with your name, your master's program and the thesis project you're currently working on.

Sira: My name is Sira Udomritthiruj. I am in the dual degree program at UW studying architecture and landscape architecture, and my thesis project is making compostable furniture out of mycelium.

Bella: What got you interested in growing furniture from mycelium?

Sira: I initially just wanted to make a piece of furniture that fruited, it had nothing to do with the material, there wasn't really an interest in the material. I was more interested in an avant-garde material and using it to create furniture, which is what I like to do.

Bella: What resources or books have you found most helpful?

Sira: I have a bunch of books, the most helpful one with growing has been Radical Mycology by Peter McCoy. It's a thick book and it's mostly about growing mushrooms and I just pulled what I could from that to grow mycelium. The other resource is Ecovative, a company that makes the mycelium composites. They have a lot of resources and they tailor to growing materials.

Bella: I've found a lot of professional resources like books and articles, but I've also found a lot of informal online forums. Do you refer to those at all?

Sira: Yeah, I have. I like to use Reddit a lot to identify my contaminants. And yeah, part of my thesis is trying to make it as low tech as possible. So those are the best resources to find different ways people do things.

Bella: How about you walk me through your process for growing one sample of an MBC from start to finish.

Sira: Well there's different ways you can grow it, but the way I have done it is I've been inoculating substrate and packing it which is similar to pouring concrete or plaster. First I grow it from grain spawn, which I purchase. I purchase grain spawn that has been inoculated already. What I do is I break it up and then I transfer it to mason jars with holes in the top. We could cover this in different categories, I guess there's the substrate and then there's the actual growing, then the preparation. And so I guess the first thing is the sterilization of everything. I found that it's actually a very easily contaminated material. I actually haven't found a solution to how to keep it alive without having it be contaminated before use or before it becomes vegetative. So I have had a lot of struggles with sterilization. But the main thing was to boil everything beyond the normal boiling point because that's what kills all the bacteria. And so I've been playing around with different times in the pressure cooker with my substrates.

Bella: How long does it usually take? What is the most successful time you've been using for sterilization?

Sira: For substrates, I've only been going for two hours. I think I've had more failures than successes with that. The best results I got was from sterilizing substrate and the most successful part of it was using mycelium from that grain spawn immediately after I get it because I don't know how the lifespan works with a mycelium block, but as time goes on, it loses its ability to grow as fast.

Bella: When you mix the grain spawn into the substrate, what ratio do you use? How do you know how much to put in?

Sira: So I started off not really measuring anything. Just because I wanted to see how messy I could be with it, you know, to tackle this side of it being accessible, and I've noticed that you kind of have to be very meticulous with all the amounts. I think it depends on the substrate. I've used a couple of substrates and because the mycelium block is like a three inch by four inch block, I've just been grabbing a tiny bit and sprinkling it in a mason jar full of substrate.

Bella: The mycelium block, you mean the grain spawn. Oh, interesting. I ordered one in a big, big bag. And online it said that I could store it in the fridge for up to two months, which was really surprising to me.

Sira: Yeah, I don't know, because I've played around with a bunch of different inoculants so I've played with plugs and then I've played with different bags with different substrate so I've had one with quinoa and then one with rye berries.

Bella: When you buy grain spawn, do you just keep buying new bags of grain spawn or do you ever propagate it?

Sira: So this first part of putting grain spawn into different mason jars of substrate is propagating, because I'm giving it new food. So it's not just a substrate, I usually mix in a bit of coffee grounds and a bit of honey water. And so what I found is the main thing is to test how much water you put in, because the substrate needs to be at its full water capacity, but if it's a bit too much, you get the wet spots. And that results in bacterial mold pretty quick.

Bella: What equipment is in your lab setup?

Sira: Well, it's my walk in closet. So it's not very lab-like, but I have two grow tents which are for growing plants. That just allows me to control the airflow better, and also allows me to have another layer of protection from air contaminants which I found to be the major source of contaminants, the airborne ones. The way I've been getting the equipment is through what hasn't worked and then I tried to solve it by seeing what's going on. And so I started with just two tents and not much else, I had gloves and alcohol. And then the way I checked my mycelium is I smell it because you can smell it when it's a bit sour with this contaminant in it where there's like a mushroom smell, it's growing. I had a round of pin mold, which once you get mold in one, and you have airflow between all of them, it usually affects all of them. And so I've had to throw away, you know, like 10 Mason jars of substrate. I've also tried to reuse substrate that has been contaminated just to see what would happen. So I had spawn that was contaminated, it was still growing, and I threw it back in a pressure cooker. And I pressure cooked it and then brought it back out and just left it and the damage was still there. Yeah, so that wasn't something you can do.

Bella: Are there any other steps you take to prevent contamination or any other tips and tricks for sterilizing the environment and your tools?

Sira: Oh, yeah, so I have a little HEP fan that circulates the air. I've moved everything into my closet, before I was doing stuff in my kitchen. Learn the steps that I learned from the book, which is to be meticulous with your movements so that you don't have things to your left and to your right and just limit how much you're moving around. When I work I'm working right in the tents. At this point, usually in mushroom growing you use a still air box, which is a box with no airflow that has holes for gloves or holes for hands to go in and work. And so that would be the way you do it. But like I said I'm trying to make this low tech, so I'm just trying to see how far I can push this material before it starts failing in that manner. So I don't have a still air box, I just work in a tent. The tent is about two feet wide, so all my movements are there within the tent.

Bella: What species of fungi do you work with and why?

Sira: So I actually started with a lot of different ones. First I started with whatever I had already. I've had a bunch of stuff frozen for like, almost five years, which is probably not good, but I started because I didn't want to buy anything else and those were all grain plugs. It was just everything, there was lion's mane, there was oyster, shiitake... but none of that worked and I moved to buy whatever was on sale from liquidfungi.com, which is probably not a good way to do things. But I just bought whichever one was on sale that were oyster because oyster is just the easiest mushroom to grow. And that's why I was using it and also because the way oyster mushrooms feed is they eat decaying, dead matter. And so that kind of played into my thesis, I wanted my chairs to disappear once they are placed on new substrate. Once I saw this couch on the street and I wanted it to disappear. And so I was thinking what if I could make furniture that could dissolve? And so my whole idea is that because mycelium is always looking to grow, if I put it on grass when it was vegetative, it would try to grow into the ground, and therefore the whole thing would just kind of disintegrate. And so that was my idea behind my thesis and so that's why I started using oyster mushrooms and then starting this quarter I'm going to try to use Reishi. Reishi is used by Ecovative in the grow kit.

Bella: That reminds me of Phil Ross's work, he grows chairs from Reishi fungi. Where do you acquire the fungi and in what form?

Sira: I use a lot of sites. I zeroed in on liquidfungi.com because they use the same grain spawn in all their kits: rye. They also sell liquid culture. I bought the smallest pre-innoculated grain bags, and then I brought some syringes[of liquid culture] because I've been trying the dip method, when you dip something into the culture to grow. So I've been trying to do that recently.

Bella: Can you tell me a little more about your process for that?

Sira: So I've seen a bunch of really elegant lamp shades made out of mycelium. My theory behind how they got there was that they use like a paper based or wood based form, and then you dip it in culture and then you let it dry. And then you put it in growing conditions and it should turn into mycelium. So I think that's what Ecovative does, I don't know exactly what they do. Their kit comes as a bag of dehydrated substrate that's been pre-inoculated and I think how they got there was they bathe the substrate in liquid culture and then let it dry and bag it up.

Bella: You said you've worked with a variety of substrates, which ones have you worked with and which have you found to be the most successful for the furniture you're making?

Sira: I haven't found success with my own growing, so much with the furniture just because of the amount. I've had a hard time moving from growing eighth inch and quarter inch samples to a full scale. Because we have had to move from growing in mason jars to bulk substrate, which gets really hard to do because there's a lot of substrate and it's hard to keep them sterile.

Bella: Which substrates?

Sira: Ecovative uses hemp, I haven't bought any hemp just because I don't want to overlap with what they do too much. But also because I want you to be able to make my stool by going to one or two stores and not have to go out and try to find hemp, which is I guess more expensive and also more specialized. I don't think you can just buy hemp wood chips. I've been using wood chips from both Home Depot and also from pet stores just as a starter kit to see what would work. I found substrates that work better are the ones that have more volume. Some of the wood chips I've been getting from the pet store or shavings, and those don't work because there's not much nutrients within them. There's other ones that people have used like wood pellets, which is compressed wood. It seems to work really well but I haven't used that. I've used Aspen wood chips which have been my most successful one.

Bella: I actually purchased some aspen chips from a pet store recently, but I've been hesitant to use it because all the literature I've read has said to use hardwood and I've found that aspen is closer to soft wood. But has it worked for you?

Sira: I mean, I've grown on it. And I think the place I'm stuck stuck on is moving from having the mycelium grow on the substrate to having the mycelium regrow on the substrate which is the next phase of the growth, when you grow mushrooms they grow in a direction and the way people get it to grow more evenly is they break the bag up basically bruising it so that it regrows into a more solid, less uniform direction. Every time I go in a mason jar, it looks like fingers growing downwards. So the pattern is basically like strands of mycelium that grow downwards, but I want it to look like a white blob. So the way you do that is you break it up.

Bella: So when you say "regrow", does that mean you start by growing it on substrate in a smaller mold? And then you have your big chair formwork that you move that to with more substrate and hope it takes?

Sira: Exactly. And so that's what I'm stuck on because the kit I used is made for that purpose. But there's no added nutrients at all, so I don't know if they put some liquid nutrients within the dehydrated substrate or not, but it just works really well. And so I think the hang up is what nutrients I need to add to the substrate for it to grow.

Bella: When you are sterilizing your substrate in the pressure cooker, I assume you add water to it in order to boil it. And then once it comes out sterilized, it's still wet right? How do you dehydrated the substrate?

Sira: I don't dehydrate it. That's for the grow kit that I buy. With my substrate, I've been actually testing different amounts of water. I've used teaspoons, all the way up to tablespoons of water just within the mason jar to see how much.

Bella: I mean after you sterilize your substrate, your straw, and then you want to go and add your grain spawn, your mycelium to get it to grow on that substrate, would you dry the substrate or does it stay wet?

Sira: So you want the substrate to be at full water capacity. Before I put the grain spawn into the substrate, if there's a puddle or like a little bit of water at the bottom, I just pour it out. I don't really dehydrate it as much as you need it to be the right temperature and it can't be too hot and so I just leave it in the pressure cooker overnight. Don't touch it. And then take it out.

Bella: Do you manipulate the substrate in any way like cutting it up or dying or using additives?

Sira: Yes and no. I've actually learned a lot from the stool I made from the Ecovative set and my next step is trying to make one out of my own substrate. But I've learnt a lot using their substrate because once I pulled it from the mold, it wasn't a uniform shape and also it had cracks in it because it didn't mycelliate in the middle because the form was too big. You know, it doesn't want to grow in that way. Once it came out it was essentially a failed stool, but then I wrapped it in a plastic bag to put it back into growing conditions. That helped a bit. Then for the cracks I actually used bits of mycelium leftover from the grow kit and I just pasted it on and then taped over a piece of plastic and it managed to grow on, so that's the welding stuff.

Bella: What material did you make the mold from?

Sira: So yeah, this mold was made from sauna tubes, which are concrete forming tubes. And so I had one on the outside and on the inside. But 3d printing has been the best mold making technique I found. The mycelium doesn't stick to the [plastic] and you don't need to finish it with lubricant or anything.

Bella: Have you used any other materials? I've got some silicone ice molds. And I'm curious if wood would work or if it would be a bad option.

Sira: I've used wood but I've put a finish on It. I've put a poly acrylic finish, so use a water-based finish, not oil-based. Otherwise you know [the mycelium] will react to it. Silicone works too because it's so stable. Silicone is used for mold making for everything because it is so stable. I've thought of eventually vacuum forming a sheet of plastic or using a milled aluminum mold, but that is for the future.

Bella: You talked a little bit about the environment in your walk in closet. How would you define a good environment for growing and what goes into maintaining that? So maybe temperature, humidity, and light?

Sira: I still don't understand the need for no light for growing mushrooms. I found light hasn't affected it much. Although when I grow in tents, it is dark. But the main thing is airflow. I found airflow is very important, otherwise it gets stagnant. Especially in the middle and at the bottom of your containers when you start growing bigger. That's the point at which you get contaminants because it's just so stagnant. So actually when you start scaling up, you actually have to aerate your substrate either by shaking the container or moving it with your hands.

Bella: How big of wood chips are you using?

Sira: My next thing is I'm trying to use sawdust now. But because of the scale, I don't think it's going to work because I have made stuff out of...I don't think it was quinoa, but it was a very round grain...and it just doesn't take due to the surface area.

Bella: Do you have anything else to add or any other difficulties you've faced?

Sira: Yeah, I think the main ones have been the contaminants and also, it gets a bit expensive after a while because I've thrown away a lot more substrates than I have kept. Once you get contaminants, it doesn't matter, you can throw it away or it can still grow with contaminants, but because I'm trying to make objects, the contaminants kind of mess up the look, which is a huge part of it. I've had a lot of success growing on cardboard, with the oyster mushrooms. I've literally just put cardboard down, sprayed it with alcohol, sprinkled a bit of coffee grounds and then a bit of the spawn on another piece of cardboard, and I just stacked it up. And I actually did that outside of the tent, it works really well.

Bella: You talked a little bit about like lab setup that it was important to limit your movements. And, like what did you describe a little bit the layout of when you're preparing things of where you have and I'd be kind of I know it's kind of a weird question.

Sira: So I just stand in one place. I have a tent on one side and behind me I have a rack with all my jars and my spray bottles. I have my gloves outside the closet because I put them on outside. And then before I go in, I use a disinfectant spray outside of it and then when I go inside I spray.

Bella: You mentioned using a when you're sterilizing substrate or maybe it was with the like grains bond that you have jars with lids with holes in them. Do you use micro tape? Or foil?

Sira: I do. I poke two holes in it. And I put micro tape on them. I only need one. I put the other one just in case I use liquid culture, but I don't think I will. I just have a roll of Microtech plastic on top of the holes.

Bella: Is that for when you sterilize the substrate?

Sira: That is just for aerating the substrate. And when I put it in the pressure cooker, it doesn't have a hole because if you have a hole in the lid all the water evaporates.

Bella: I think that concludes the interview. Those were really helpful answers. Thank you for your time!

INTERVIEW 2

Interview with Sira Udomritthiruj
Date: May 15, 2024
Duration: 47 minutes

Bella: What were some of the biggest failures you had with growing? I'm just curious about what went wrong. Whether it was mold or if it was not giving it enough time to grow or letting it grow for too long?

Sira: I don't think it was the time constraints. All my experiments I cut short too early, but I didn't know until I did.

Bella: How long did you let them grow?

Sira: I gave it like two weeks and I realized that when I was growing my own material it needed like four to six weeks to grow.

Bella: Four to six. Was that for the bigger ones or for the smaller ones?

Sira: It just took the mycelium a lot longer to spread. I actually had more success taking it out of the mold and putting it in the jar and it kept itself alive. It was wet inside from the mycelium and that allowed it to cover the hole.

Bella: So four to six weeks. Wow, how long did you let the big stool grow for?

Sira: That was two weeks. So that's a product, right? So with the product [kit], it's just labeled. I asked them why they used hemp and why they used Reishi and they said they landed on both after testing like 500 substrates and mushroom species.

Bella: When you took them out after two weeks, how did you know that they needed more time to grow? Was it just that they were falling apart?

Sira: Yeah, I think when you look at it, there's different stages of mycelium. You can still see the wood pieces in it. And I think it's supposed to be completely covered. It's supposed to look like the primer canvas with gesso, just a little patches of light in so I actually took it out and I could see that it looked more like a substrate than mycelium. So I wrapped it up in a bag to let it continue to grow in good conditions.

Bella: When you use a grow kit, what comes with it?

Sira: Dehydrated substrate, so it's pre-inoculated.

Bella: So they've already grown it on rye berries probably and then transferred it to the final substrate?

Sira: Yes

Bella: Did you do anything to modify the kit at all? You've mentioned adding honey, coffee or water.

Sira: In the kit, they suggest water and flour. And in the beginning I just estimated the amounts and it still worked. I found, after all my attempts, that it didn't really matter how much water and how much substrate is in there. The mushrooms will find a way to grow. It's just that if you have too much substrate in there, there's not enough oxygen so it doesn't grow a lot and if you have too much water it only goes up to the point where it won't drown itself. If you have a jar of substrate and half of it's submerged, it will only grow to the half that's not submerged. The way I got to be able to grow my own material is through learning with more attempts. You need to learn from what is going wrong in the first attempt. I was doing it on our kitchen counter and my dogs running around and I smoke inside sometimes. So it grew, but then within a week there was all the airborne contaminants on it and there was pin mold. And so I realized maybe air is more important than I thought. So I moved into a tent and then the second attempt I messed around with the substrates and then I guess I didn't realize this until afterwards, but the substrates kind of don't matter. Like what, what you grow it on. If you use a strain that is aggressive, like the ones we're using, so oyster and reishi, are just really aggressive and want to grow. Oh and also I realized on the second attempt that air circulation was needed as well. Because I had transferred everything into mason jars and I poked holes in them for airflow, but that wasn't enough. So it still grew, but after a couple of weeks with the still air, contaminants started growing. So that's when I added the air purifier.

Bella: And so the contaminants were mostly pin mold and cobweb mold? Any others you identified

Sira: Trichoderma,it's the green mold. That comes from bad substrate. That was my third attempt. I had been kind of leaving my stuff to sterilize without paying attention, so sometimes it fell below temperature and without even inoculating the substrate, if I left it out, it would start growing green mold. After that, I tried to mess with my substrate, so I pre-soaked them so that the water capacity was full. Because before I also thought I had an issue with having too much water, but the substrate's water capacity wasn't terrible.

Bella: You mentioned in the past that you'd add a little water while it's growing, and kind of treating it like a plant and knowing how to take care of it. I have an experiment running now where I have multiple different molds with a mix of grain spawn and substrate in there. And I'm not sure when to know if I should add more water, like in the next week. And how much water and do you just kind of sprinkle it or drizzle it over?

Sira: The way I add moisture is spray bottle and I don't actually spray the mycelium I spray the walls of whatever the container is and let it drip,

Bella: But what if it's in the mold?

Sira: If it's in a mold, I put it in a Ziploc bag and spray the ziplock bag so that the water content is inside and can't escape. And that has worked.

Bella: But if you put it in a sealed bag, then it can't get air, right?

Sira: Yeah...mmmm...that's just how I got moisture in it. But I found that it creates its own moisture until it doesn't. So that gets more into mushroom growing. Unless you just let it grow and then you spritz it when it looks dry.

Bella: For honey, what do you do? I had a bunch of grain spawn leftover, I made little mold samples this week, and my grain spawn was not looking so good. So I thought maybe I'll try to add a little honey and I took a little honey, it was really crystallized and old, and I just heated it up with water, let it chill, and then poured it in the grain spawn bag. It was maybe a third of a cup and it was a pretty big bag. And then I just stirred it up inside the bag with a filter on it. How did you add honey?

Sira: The way I use honey is I pressure cook it with water and use that as my liquid when I was sterilizing my grain.

Bella: Oh, so in the very beginning, before you start the growth process. Okay, so it's not something you add partway through?

Sira: No but you can and that would feed it with the same concept as adding coffee or flour, I think.

Bella: I didn't sterilize my honey. Just because it should be okay. Honey is antimicrobial.

Sira: it should be. It should be just a matter of the amounts, I guess. What I would do with adding nutrients is I add it into the substrate and shake it, so it's everywhere.

Bella: Why are you worried about too much honey?

Sira: So for example, if you have a mason jar, if you put honey in, it's gonna want to drip to the bottom. And then it's gonna be in the bottom and if you add your grain spawn to the top, then it's not going to interact. And so I just wanted the nutrients to be on the substrate.

Bella: I see. In the past, you've mentioned caring for the mycelium and the samples as a pet. And we're treating it like a plant. And you've mentioned spraying it with a spray bottle but is there anything else you do to check up on it?

Sira: If you don't check up on it, and it's still in its environment, and you don't mess with it, it should just stay as it is. It should just vegetate, and it might release some yellow liquid. That's discharge. And that's just a chemical reaction from fighting off contaminants.

Bella: Maybe that's what I noticed on my first try when it got moldy and I saw some yellow there and I thought the yellow was mold, but maybe it was discharged. Interesting.

Sira: On my third try, I soaked the substrate before I inoculated it and that helped a lot more than just having the water steam through the substrate.

Bella: What does that process look like?

Sira: I need a little cap like a salt sprinkler for my mason jars and I just filled the whole thing up with water, put the substrate in there, gave it a day for everything to be wet, and then I just emptied out all the water.

Bella: Okay, and then do you sterilize it in the pressure cooker?

Sira: Yes, and then I sterilize it in the pressure cooker. And so with that process, I tried three different grain sizes. I tried with dust, which was super fine. I tried the aspin, which was pet bedding, so it was like a quarter inch to three eighths. And then I tried cedar shavings, which was advertised as horse bedding, so they were bigger. And I put my three different amounts of each substrate together in another mason jar. It didn't matter how much substrate was in there, all of them grew a lot more than any of my other attempts.

Bella: Did you find one sample was more successful than the others in terms of how sturdy it was and how much it stuck together?

Sira: Yes and no. It's just a matter of letting it grow. I think I pulled them out at the same time. And the cedar one was the only one that had kind of spread all around to make it an all white object. The other two I put back into the mold and then in a ziplock and then I removed that and I ended up putting it in a mason jar with air flow, out of the mold because at that point it was a shape already. I monitored it by checking it every day and seeing how much it myceliated.

Bella: I'm surprised to hear the sawdust worked well because when I think of sawdust, there's not much surface area for the mycelium to grab onto, so it really stuck together? I also wanted to know if there is any equipment that you wish you had?

Sira: A massive walk-in fridge room to be the living environment, so I didn't have to have all these smaller living environments. For example, I'm growing this new stool, and I'm making, essentially donuts. I'm gonna stack them and then wrap it in a bag and hope it grows together in the bag. If I had a fridge room, I wouldn't have to find a way to enclose it.

Bella: Why would you want to put it in the fridge?

Sira: It's less about the fridge and more about having a more sterile environment. I've seen some people growing mycelium material on YouTube and they just had a walk-in room with a sealed door. And that was the environment. I'm pretty sure it's not a fridge, but it is a special room.

Bella: So it's room temperature, maybe 65 degrees? Not cold right?

Sira: Right. They didn't put it in a mold, they just put the piece in that room, closed the door, and it myceliated. So that would have been really helpful. I think I had all the equipment I needed for the mycelium part. Because I'm sure you saw too, but there's so many different low-tech techniques you can use to grow mushrooms. And so that kind of translated to growing mycelium and there's so many things that people have figured out like using a storage container for batch substrate inoculation.

Bella: Have you tried growing outside yet? Because in some of the papers I've read for when they've made bigger structures out of mycelium-based composite, they didn't have a room big enough to be growing such large objects. So they grew them outside and they were successful. And that's made me nervous because outside is full of pollen and flying contaminants, but I'm trying it this week so half of my samples are growing inside and the other half I put outside underneath my deck. And I'm growing them in these little metal baking pans that I covered in plastic wrap and poked a couple holes in them. I also have the perfect size Tupperware containers that fit right over them, but so they still have space on either end to allow airflow and that's just for you know, rain protection even though it's under the deck. And yeah, what are your thoughts on growing outside? I'm not sure if it's gonna work for me yet.

Sira: I think you gotta let it grow- I'm sure all those guys did too- grow to a certain point before putting it outside.

Bella: It's grown a bit in the grain spawn bag already, but then I took the grain spawn that has already had a little bit of growth and put it in with the substrate and put it outside.

Sira: Because if you think about it, mycelium and mushrooms, especially oyster and reishi, are actually aggressive and grow in houses and like in bathrooms and stuff. But then at the same time growing this stuff from scratch, in its infancy stages, it's so prone to everything. So it's just a matter of finding when it's no longer prone to stuff. For example, I brought some samples that I had just grown into studio, and someone was touching it. And then I came back the next day and the top of it was green, it had Trichoderma. That was just from touch.

Bella: For my thesis I'm trying to learn from all my failures and include that in this little booklet. So hopefully students can learn from what I've done wrong. And I'm curious, what are the things that you would have done differently in your trials and experiments?

Sira: Well, I would have not tried to grow my own material. I think that was too big of an undertaking. I underestimated the complexity. I had used a grow kit, I actually got some oyster grain spawn online, but I thought it would be as easy as moving that into a form and it wasn't. My thesis has become more of a landscape matter, in which I've just been learning about fungi and how they could help break down materials or replace materials that come from broken down landscape, just how they can really enhance the wealth and health of the landscape. And so that's become my thesis as opposed to growing furniture out of mycelium. So I wouldn't have built my own material. I would have just contacted the grow kit company and asked them for as many bags as possible and just focused on furniture design. But going forward I am now trying to turn all the stuff I've learned about the properties of mycelium and how it grows and how it doesn't grow and use that with processes that you associate with the built environment. So like, joining, cutting stuff, you know, making parts as opposed to a whole object. And so I'm just trying to test a bunch of furniture making methods with mycelium and to do that I would need to explore the mycelium more to create material samples that would match these processes.

Bella: If you had to or if you wanted to continue trying to develop your own material, what would you do differently? I know you mentioned having a better room to grow it in or limiting contaminants through touch or air flow, is there anything else you can think of?

Sira: I think what I said in the beginning is it's a time thing because I was doing it pretty intensely. All until I grew that stool, I didn't do anything but my thesis pretty much every day. And even that wasn't enough because it was the time constraints that came with mycelium, I was on the mycelium's schedule. I couldn't force it to go any faster. And I think I lost a lot of time because in the beginning I was trying to force it to do stuff and then that meant that I was stressing it and so my grain bags from the beginning, I thought I only had to buy one or two grain bags and keep it going, but I had to buy a new grain bag three times in the end because I was just rushing things and I was trying to get it to work for me and it wasn't.

Bella: Do you think you'll keep growing when you graduate?

Sira: I'm gonna contact a company and see if I can get a bunch of material and see if I can do anything to help them through furniture design.

Bella: How exciting!

Sira: I thought from the beginning that it was so simple, because growing mushrooms is the hard part. Mushroom growers grow mycelium to grow mushrooms, and so that's not that hard of an endeavor to do because it's not even the mushrooms it's like the pre-mushrooms.

Bella: I've been thinking the same thing because I've had friends who grow mushrooms and they say it's so easy and when I was younger I got one of those little kits online to grow, I don't know, oyster mushrooms or lion's mane or whatever. And it was so easy because it comes ready. But I mean in those cases we're not introducing a new substrate, right and we're not trying to make it something beautiful.

Sira: And also they have benefit of adding whatever nutrients they want to it, like soil, you know putting soil in any of our examples will just not work because soil isn't structural and so a lot of people when they mix substrate they mix in soil for nutrients, and soil obviously occurs in the real world. The mushrooms like it.

Bella: Have you seen examples of materials that have soil in them in the end?

Sira: I have not. The only stuff I've seen is pure wood.

Bella: Do you think that would cause any issues? Adding a little soil in?

Sira: I don't think it can be a little, I think it needs to be a lot more than a little soil. And soil decays, so it would just create cavities. It might not be a problem, but it would for a building or architecture.

Bella: But wood also decays.

Sira: But at a much slower than soil, especially as a material unless you bake it in which you make it a stable thing is mostly for disposable stuff. So like formwork for like all this stuff right here. Because when they make formwork for this, they probably use it once and then plywood because of all the water in the concrete warps everything and they can't use it. And so it's just plywood that's going to end up in landfill that has been used once

Sira: I think that's probably the best use for Mycelium is stuff like that. In landscape, there's a bunch of stuff that would be laid out on landscape that we want to disappear that we usually use

organic materials for water barriers, barriers, stuff like that. Stuff we want to disappear.

Bella: Okay, so I've been trying to understand the water absorptive properties of mycelium-based composites. I've heard two different things. When I was in Gundula's class, we had this woman come in who was a biologist and she had a student who made this crazy robotic arm and covered it in mycelium because mycelium does not absorb the water, it has hydrophobic properties. And so then this robotic arm is waterproofed essentially. But I've also read in research papers about using mycelium-based composites as a building material, that it's not a good idea because it does absorb water. And so from hearing those two things, I've come to the conclusion that it's probably the substrate that's absorbing the water and not the actual mycelium because they were saying it's not good to have in the building envelope because it would absorb water, but I'm assuming it would maybe just be the substrate.

Sira: I think you need to leave it to grow as much as [possible]. So on my stool, the top is more myceliated than the body. And so on the top, you can't see the substrate at all, and like I said, it looks like gesso. I think that is probably what makes it hydrophobic. But if you leave the substrate visible, it will go into the substrate and break it down like that but also, I think curing it will do a lot because I think with building envelopes, mycelium has a lot more stuff it could try to inoculate as opposed to a robot in which you can assume everything on there is metal. So the mycelium has nowhere to go and if it's killed then it's killed, but on a building, whatever's behind the envelope, they will try to move into that I'm assuming.

Bella: I'm curious how they even got mycelium to grow over the arm like a glove, because that's so cool.

Sira: Have you seen the mycelium canoe (Mycelium canoe was made by Washington State University student, Katy Ayers)? A lady who grew a mycelium canoe and it's pretty good. I think they just made a frame and they wrapped it in cling film with mycelium.

Bella: Well then that completely disproves my worry about it being water absorbent.

Sira: It kind of looks like a washed away lock. So that's the aesthetic issue with this whole thing. For me too, because I'm trying to make a furniture product and that just doesn't look professional to me.

Bella: Yeah, so when I submitted my first thesis proposal, I was really inspired by furniture and all the mycelium products, but I thought 'these are ugly'. So my first proposal was to try to improve their aesthetic. And I quickly learned that is a bit too ambitious for me as someone who had never grown anything before. So then it turned to okay, well can I even figure out how to grow this.

Sira: So that's how they did it. So they just covered the whole thing in mushrooms and let it myceliate. And then I'm sure after a bit when they saw the progress they removed all the barriers, because none of that is breathable material, so they removed all that.

Bella: Did you do anything to explore manipulating the aesthetics? I know you said adding flour to be white and substrate size- anything else?

Sira: No, I didn't even get to that. My whole thesis was to make furniture out of mycelium and all I got to was like the first stage of material development. Yeah, it's like an eighth of what I wanted to do. And I was working at it a lot.

Bella: I'm curious if you've seen any other uses within the context of architecture, like you mentioned things that are disposable. And mostly what I've been reading is that it's best used as a substitute for Styrofoam. Like you were saying, throw away packaging for building materials. And then also other foam-like things like door cores was something I read, which was really cool. And then obviously insulation. And I've seen some really beautiful acoustic panels.

Sira: In furniture, there's a whole list of materials. All the materials that IKEA uses. I think all the materials that are used in furniture; all the melamine and OSB which are toxic. There's a bunch of formaldehyde in the adhesives of materials like plywood. And there's also all the upholstered stuff; the foam is all polyester inside. I think that was probably a pretty good use for mycelium to just replace all those parts if the furniture is only going to last, you know two to three years maybe five at most anyways, then you might as well make it out of materials that can, if left on the curb like most furniture is, can be absorbed into the ground to help remediate the soil. So that was my whole thesis.

Bella: Well said. I was thinking about how Mycelium-based composites are biodegradable, but not all of them are compostable, because it depends on the wood. And didn't you say that the wood saw dust from the [UW fabrication lab] was from treated wood so it wouldn't be in line with your work?

Sira: I think that would work though. So that was another whole thing that I never explored. I think growing mycelium on dust from MDF and plywood might work. There's an example that Peter McCoy did, he grew oyster mushrooms on cigarette butts. And it took to the cigarette butts and actually fruited and so I'm sure you can use dust from wood shops, but you need to train it. You need to introduce it to the substrate through a lot of testing before it would do that.

Bella: I think you could definitely get it to grow on MDF because I had found some projects where they grew it on plastic. And if you have plastics in there or toxic materials, why not MDF? Sira: I've seen Lion's Mane grown on Styrofoam blocks and you can taste the styrofoam.

Bella: Ew, that's crazy. Interesting. But yeah, I guess this is where the field is headed, which is pretty exciting.