# MyCo Domicilia

BDC 2020
University of
Colorado at Boulder

For the Biodesign Challenge 2020

**Instructor**
Mirela Alistar PhD

**Team**
Fiona Bell
F. Ria Khan
Theresa Matick
Malika Rakhmonova
Arva Syed
Shenali Uragoda

# Contents



*Indexed words are annotated with a superscript, or number that is set slightly above the type line (e.g. biobased[1])

# Introduction

# Mushrooms As A Domestic Medium

F. Ria Khan

04

Mycelium[6] is the vegetative structure for fungi that produce mushrooms. Think of it as the root system while mushrooms are the fruit [6]. However, one can also think of it as one of the most promising biodegradable[2] materials for fabrication[3] today.

Exploration in eco-friendly and biodegradable materials for fabrication has been gaining exponential traction over the years in many disciplinary fields such as: Fashion, architecture, bio-engineering, art, product design [45]—the list goes on. And why would it not? New materials mean for new pursuits and methods for innovation, and innovation is something we need now more than ever. In the age of plastic and over-consumption, we've found our Earth in crisis, and we'll be facing truly worrying con-sequences in the near future if we don't make changes soon.

As a response, the world of fabrication has convened to address the crisis by producing some interesting solutions to our sustainability problem—like using mushrooms. Mycelium has been circulating around in recent times as a highly versatile biobased[1] and biodegradable material, and its affordances are plentiful.

When mycelium is baked, it can take on many different forms, from sturdy structures like bricks [33] to flexible material akin to leather [12]. Before the baking process, it can also grow into the shape of whatever container it's in, making it extremely dynamic in scale and shape. Additionally to all this, it is waterproof [11], lightweight [47], and with fire-retardant properties [18]. Furthermore, what is most significant to mycelium in terms of sustainability is that it's biodegradable and low-cost/easy to source.

Yet, the uses of mycelium haven't reached their full potential since growing mycelium requires lab procedures, which not everyone has access to. However, much of this issue can be solved with better considerations toward accessibility to the process; such that anyone, from whatever background or experience, would feel compelled to engage with mycelium and its possibilities in sustainability. Thus, we introduce our project for the 2020 Biodesign Challenge, MyCo Domicilia.

So, what is MyCo Domicilia? Well, it's what you're reading right now. This book entails our creative explorations as a "do-it-yourself" or DIY resource for fabricating with mycelium for common household, or domestic, artifacts. We've chosen a



book as the format of this detailed resource, while also including an accompanying website [15] and social media [26][27] to maximize our reach and accessibility to the community.

With MyCo Domicilia, we want to stimulate and help grow the free, creative market and as a result, promote sustainable practices and empowerment through accessibility. Our goal is to inspire anyone of any socio-political status, economic background, creed, and even bio experience to embrace eco-friendly changes in their lives.

We've implemented a way to achieve these goals by constructing MyCo Domicilia as a suite of recipes for building everyday objects that feel simple, affordable, and easy to follow so that anyone reading can feel empowered to remake these creations. We believe that contributing to the world of DIY home projects with our user-friendly mycelium additions will expose people to sustainable materials and facilitate excitement to participate.

However, in developing these recipes, it wasn't a Biodesign *Challenge* for nothing. During the competition, the pandemic generated by the COVID-19 virus had reached the United States. This meant our University's campus had to be shut down, leaving our team estranged from each other and facing the challenge of developing new methods for communication and collaboration.

However, this fortunately meant we got to test the DIY aspect of our work and create our recipes at home—validating that they

can be easily replicated by anyone. We also formulated another intriguing and exciting section of our book for our teammates who didn't have access to mycelium after the shutdown—speculations. Here we effectively speculated future works based on thorough research for feasible recipes that could've been done had it not been for the pandemic. In this sense, we invite people to speculate with us and further the idea of accessibility by eliciting more imagination in the possibilities for mycelium.

All in all, MyCo Domicilia embodies and facilitates the idea that we can all make a difference in helping the Earth by embracing eco-friendly modes of design and making, all while having fun in the comfort of our homes.



# General Materials and Processes

*Many of the recipes use similar materials and processes. To keep things concise, we created this handy section of general materials and processes as a shorthand. Keep a tab on this section as all recipes will refer to it. Happy making!*



## Mycelium

*-Mycelium and growth medium[5] from GROW.bio [14]*
*-Unbleached all-purpose flour*
*-Water*

## Tools

*-Measuring cups*
*-Spoon*
*-Mixing bowl*
*-Non-latex gloves*
*-Isopropyl alcohol*
*-Plastic wrap*
*-Oven*

# Primary Growing Process

**Steps one** Sterilize[7] gloved hands, then tools and work-space with isopropyl alcohol (make sure to rub the materials with alcohol until its evaporated)

**Step two** Mix 4 tbsp unbleached all-purpose flour with 3 cups tap water

**Step three** Open the bag of mycelium and medium mixture and pour the flour and water mixture into the bag

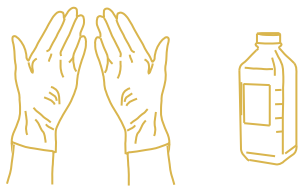
**Step four** Seal the bag with tape (have white filter patch on the bag uncovered to allow air exchange)

**Step five** Shake the bag so that everything mixes together (at least 1 min.)

**Final step** Store in a dark, dry place for 5 days



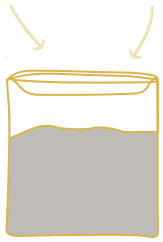
Step one



Step two

Step three

Step four



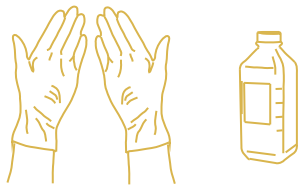
Step five

# Secondary Growing Process

| | |
|---|---|
| Steps one | After 5 days, take out the bag (should be mostly white) |
| Step two | Sterilize gloved hands, then tools, workspace, and molds (again using isopropyl alcohol) |
| Step three | Pour mixture into large mixing bowl |
| Step four | Break mycelium apart with hands |
| Step five | Add 4 tbsp flour to crumbled mixture |
| Step six | Mix flour in using hands (at least 1 min.) |
| Step seven | Fill mold with mixture |
| Step eight | Cover mold with plastic wrap |
| Step nine | Poke holes in plastic wrap (approx. 1“ apart) |
| Step ten | Place molds in incubator[4] or container that can maintain a temperature of 20-25C°/68-77F° |
| Final step | Put unused mycelium mixture back in bag and seal, place bag back in dry place for later use |



Step one

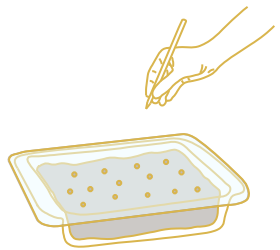


Step two

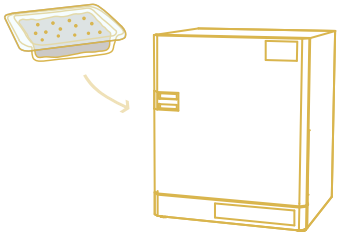
Step three

Step four

Step 7, 8, & 9



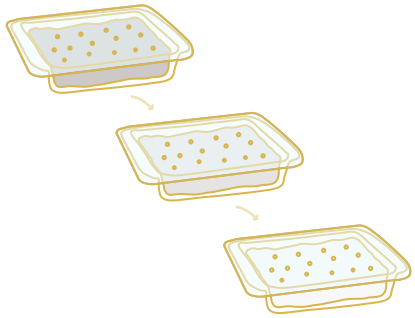
Step ten



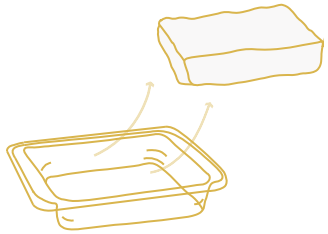
# Baking Process

| | |
|---|---|
| Steps one | Let the mycelium grow in the molds until molds are completely white |
| Step two | Remove mycelium from molds and let dry for 1-2 days |
| Step three | Once dry, preheat oven to 95C°/200F° |
| Step four | Bake in the oven for 30 min. |
| Final step | Remove from oven, let cool |

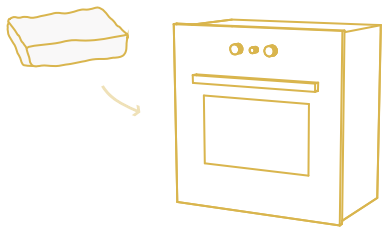
Step one



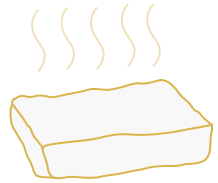
Step two



Step 3 & 4



Step five



# Recipe 1 On MyCo Fashion

Fiona Bell



There are a variety of sustainable biobased materials that have been used in fashion, including bioplastic, kombucha, and a variety of starches [41]. Examples include AlgiKnit's seaweed yarn [3], Vollebak's wood pulp and algae shirt [42], and the EcoRain Poncho made from a sugarcane-based bioplastic [10]. However, unique from these materials, mycelium is suited for wearables due to its strength, light weight, shape-ability, water and thermal resistance, and DIY qualities.

In this work, we chose to elaborate on the idea of mycelium accessories, which were initially tackled by a group from the University of California, Davis. While the UC Davis team decided to make large pieces with embedded electronics [41], we chose to create more practical jewelry in the context of everyday wear.

To accomplish this, we grew a pair of stud earrings, a pair of hanging earrings, a teardrop-shaped pendant, and a heart-shaped pendant. These pieces were inspired by popular, minimalist styles that are commonly seen at department stores.

Small metal pieces were used to complete the jewelry, such as the necklace chain and earring backings. While these additions are not biodegradable, they add functionality, and durability to the pieces. When the pieces are no longer wanted, the mycelium components can be composted, while the metal parts can easily be removed and reused for new pieces, highlighting the importance that both composting and recycling have on our material waste.

In our current world of fast fashion, pieces quickly go in and out of style, going from the traditional two seasons (Spring/Summer and Fall/Winter) to over 52 “micro-seasons” per year [2]. While there are many issues concerning this trend, eco-friendly brands can adapt to this new reality in a positive way by creating pieces that can be composted, recycled or re-used. In this case, we provide insight into how mycelium could be used as a sustainable material in the scope of fashion.



## Molds

*-Sculpey clay*

*-Jewelry (pendant and earrings)*

## Mycelium

*-See general materials*

## Tools

*-See general materials*

*-Sewing needle*

## Materials

*-Pendant chain, wire, or string*

*-Earring backings or hooks*

# Method

**Steps one** Mold Creation Process

1. Roll out Sculpey clay so that it is approximately 2cm thick
2. Take jewelry (pendant, earrings, ring, bracelet, etc.) and press into clay
3. Carefully remove jewelry from clay
4. Preheat oven to 120C°/250F°
5. Bake clay molds for 15 min.
6. Remove from oven and let cool

**Step two** Primary Growing Process (see general process)

**Steps three** Secondary Growing Process (see general process)

**Step four** Baking Process (see general process)

**Final steps** Final Artifact Process

1. Pendants: Create a small hole with a sewing needle in the top of the pendant and attach a chain, wire or string of your choosing
2. Earrings: Glue metal backings or hooks to the earrings

# Recipe 2

# Mushrooms for Dinner(ware)

Fiona Bell



Tableware is versatile in nature, encapsulating the variety of items we set on the dinner table including, but not limited to: Plates, bowls, cups, and cutlery. Similarly to furniture and fashion, tableware bridges the gap between function and beauty, firmly establishing itself in the world of 'craft'. The Victoria and Albert Museum, which is the world's largest museum of applied and decorative arts and design, alone, houses an "encyclopedic" collection of ceramic tableware that ranges from 2500 BC to the present day [40].

The artifacts we use to dine undeniably give insight into a society's culture, reflecting values such as functionality, beauty, wealth, community, and more. For example, the Brown Betty Teapot illustrated the life of the working class during the Victor-

ian Era. While most of Victorian high society drank tea from highly ornate bone china, the Brown Betty was made from a local red clay that retained heat well [36]. It was also inexpensive, easily replaced, and made an excellent cup of tea, reflecting the working class' values in functionality and affordability over beauty [37].

Over time, materials such as porcelain, pewter, silver, and gold have been exchanged for more modern materials such as plastic and acrylic due to their lower cost and durability—showcasing current society's value in functionality and affordability. However, the rising concerns about pollution and global warming have caused people to value sustainability as well. Unfortunately, sustainability tends to contradict affordability; however, to challenge this, a market for low-cost, biodegradable, and biobased products has opened up.

While mycelium does not have the same range of mechanical properties that plastic does, it is hydrophobic and heat resistant, making it a realistic sustainable substitute for more traditional tableware materials. Its natural aesthetic beauty and biodegradability also reflect and promote our society's rising value in sustainability.



## Molds

*-2 Bowls (one slightly larger than the other)*
*-2 Cups (one slightly larger than the other)*

## Mycelium

*-See general materials*

## Tools

*-See general materials*

# Method

| | |
|---|---|
| Steps one | For the mold, obtain two bowls or cups (one outer and one inner) |
| Step two | Primary Growing Process (see general process) |
| Step three | Secondary Growing Process (see general process) |
| Step four | Baking Process (see general process) |
| Final Step | Enjoy! |



# Recipe 3

# Myco Phonecase:

## Apple® in a Mushroom

Shenali Uragoda



Phone cases today are typically made out of silicone, rubber, metal, and leather materials. While most of these materials are widely popular for their accessibility and low costs for mass manufacturing, they have their downsides [39]. As to be expected, plastic cases are far from environmentally friendly, while leather cases are expensive and require external resources like land and irrigation water for the cows they source materials from [9]. Metal cases can easily get overheated and have issues with transmitting wireless signals [23]. Moreover, silicone cases, well, they can be just too difficult  to clean and can end up looking low-quality [39].

So, what is a material we can find that's environmentally friendly, low-cost, and doesn't interfere with our electronics,

all while still maintaining quality? Look no further but the Myco Phonecase, a customizable case that can be fabricated out of mycelium. These cases encompass all the values listed above and can be something that the consumer is empowered to create and customize themselves.

While there are companies who manufacture phone cases that are sustainable and eco-friendly, many of them are expensive and cannot be tailored to a consumer's particular tastes. The Myco Phonecase on the other hand is easily accessible, cost-efficient, and something that anyone can have fun making.



## Molds

*-Oomoo 30 silicone rubber compound kit*
*-Old phone case*
*-Rectangular container*

## Mycelium

*-See general materials*

## Tools

*-See general materials*

## Materials

*- Mixing bowl for mold*
*-(Optional) Acrylic paints*

# Method

**Steps one** Mold Creation Process

1. Pour part A and B in a 1:1 ratio in mixing bowl
2. Seal oomoo kit jars to limit exposure to air
3. Mix part A and B in the bowl until mixture is a lavender color
4. Mix thoroughly ensuring that there are no colored streaks in the final mixture
5. Glue the back of the phone case to the bottom of the plastic container (case should be facing up in the container)
6. Pour the silicone mixture into the container making sure to fully cover the phone case up to the surface of the case
7. Wait 6 hours for molds to fully cure
8. Gently remove phone case from the mold

**Step two** Primary Growing Process (see general process)

**Step three** Secondary Growing Process (see general process)

**Step four** Baking Process (see general process)

**Final steps** Final Artifact Process

1. Optional: paint phone case (let dry before fitting phone into case)
2. Call a loved one

# Recipe 4

# Mushroom *Toy* Blocks

Arva Syed



In today's world, toys for kids are regularly made out of plastic, a material that is non-biodegradable and in turn is left to build up in the environment. It is even analyzed that 8 million metric tons of plastic end up in our oceans per year [38], affecting fragile ecosystems. With this in mind, this project is meant to introduce kids to not just play with biodegradable toys, but also to be included in the process of making these toys in order to promote learning about sustainability in a fun and empowering way early on.

Mycelium is a wonderful material for this endeavor and is suitable for everyday play because of its sturdiness. Also, since mycelium can fill the shape of most any mold it grows in, it is a fantastic material for making custom toys. Kids can easily make

their own modifications to the design by carving the molds that make the toys or basing the molds on pre-existing items.

For this project, we made mycelium building blocks in the shape of tetrahedrons [8], or three-sided pyramids, which can be assembled into any configuration you can imagine [20]. The molds for the blocks are made of silicone rubber and use pre-constructed blocks (which for this particular project, we 3D-printed with recyclable PLA [4]) to make the shape of the mold. The mold can be reused to make many replicas of the blocks instead of having to waste more plastic on additional copies. These little pyramids also connect together using neodymium magnets that can be reused once you are ready to make something new. Thus, this project also demonstrates the power of recycling when having to work with materials that are non-biodegradable.

By including kids in the process of making their toys in this context of biodegradability and recycling, we can introduce them to sustainability and talk about why it is important to be aware of what we put out into the environment, all while engaging in play and fun. So, when you want to give your kid a unique present that will teach them life-long lessons on sustainability, you can feel good about using these Mushroom Toy Blocks.



## Molds

*-Oomoo 30 silicone rubber compound kit*
*-3 PLA 3D-printed model blocks*
*-Shoebox or shoe box-sized container*
*-Disposable container large enough to fully submerge blocks*

## Mycelium

*-See general materials*

## Tools

*-See general materials*
*-Tape*
*-Scissors*
*-Exacto knife*
*-Super glue*
*-Pencil*

## Materials

*-Mixing bowl for mold*
*-Newspaper*
*-Small neodymium magnets 3/8" diameter, 1/16" thick (4 per block)*

# Method

*Please have kids under adult supervision when creating this project (some tools will need adult assistance as well).*

**Steps one** Mold Creation Process

1. 3D print 3 model blocks using provided STL file [5] or find an object to base the blocks on
2. Cover workspace with newspaper
3. Once printed, tape the model blocks securely onto bottom of disposable container (make sure they are in direct contact with the surface of bottom of the container)
4. Place the container in a shoebox
5. Put on non-latex gloves and long sleeves (could lead to an allergic reaction or chemical burn if you are allergic to latex)
6. Pour part A and B in a 1:1 ratio in mixing bowl
7. Seal oomoo kit jars to limit exposure to air
8. Mix part A and B in the bowl until mixture is a lavender color
9. Mix thoroughly ensuring that there are no colored streaks in the final mixture
10. Pour the silicone mixture into the container, making sure to fully submerge the blocks
11. Wait 6 hours for molds to fully cure
12. Cut molds out of the container with scissors
13. Use scissors to extract blocks from mold



**Steps two** Primary Growing Process (see general process)

**Step three** Secondary Growing Process (see general process)

**Step four** Baking Process (see general process)

**Final steps** Final Artifact Process

1. Mark the center of each face of block with a pencil
2. Using an exacto knife in a twisting motion, cut shallow holes 3/8" in diameter where marking are (adults only should handle this step)
3. Put super glue at the bottom of the hole and on one side of the magnets
4. Drop in magnets into the holes with the super glue side making contact with the bottom of the holes
5. Use the blunt end of the pencil to pack the magnets down into the holes so that it adheres to the bottom of the holes
6. Let glue cure for 24 hours
7. Enjoy your new toy!

# Recipe 5

## MyCo MyDecor

Fiona Bell



In the age of sites like Pinterest [30] and Instructables [43], it is easier than ever to start a DIY home decor project. Successfully making something for your home is not only rewarding but also acts as a form of self-expression and reflection. It is also just plain fun! While wood, paint, clay, and resin are popular materials among DIYers, we propose mycelium as the more sustainable option. Unlike materials such as resin [5] or modeling clay [1], mycelium is both biobased and biodegradable [32].

On top of meeting typical craft material requirements, such as shape-ability and ease of use, mycelium's uniqueness as a living material adds artistic value. This leads to improvisation, or improvising on the creative methods of making based on this uniqueness. Because mycelium is a living thing, there is only so

much that the artist can control. However, rather than a constraint, this uncertainty with control can facilitate imaginative solutions, thus introducing natural shapes, colors, and other intricacies novel to each individual piece.

While most of our mycelium products have more of a functional purpose, we believe it is equally important to explore how mycelium could be used as an artistic medium due to its natural aesthetic beauty. To demonstrate this, we chose to create a delicate hanging piece of wall art in the shape of a moon based on both popular DIY home decor ideas and mycelium's natural colors. This piece opens up a discussion of how mycelium can be utilized for DIY design practices for everyday self-expression in a novel, improvisational way. All while doing it sustainably.

## Molds

*-Circular plastic container*

## Mycelium

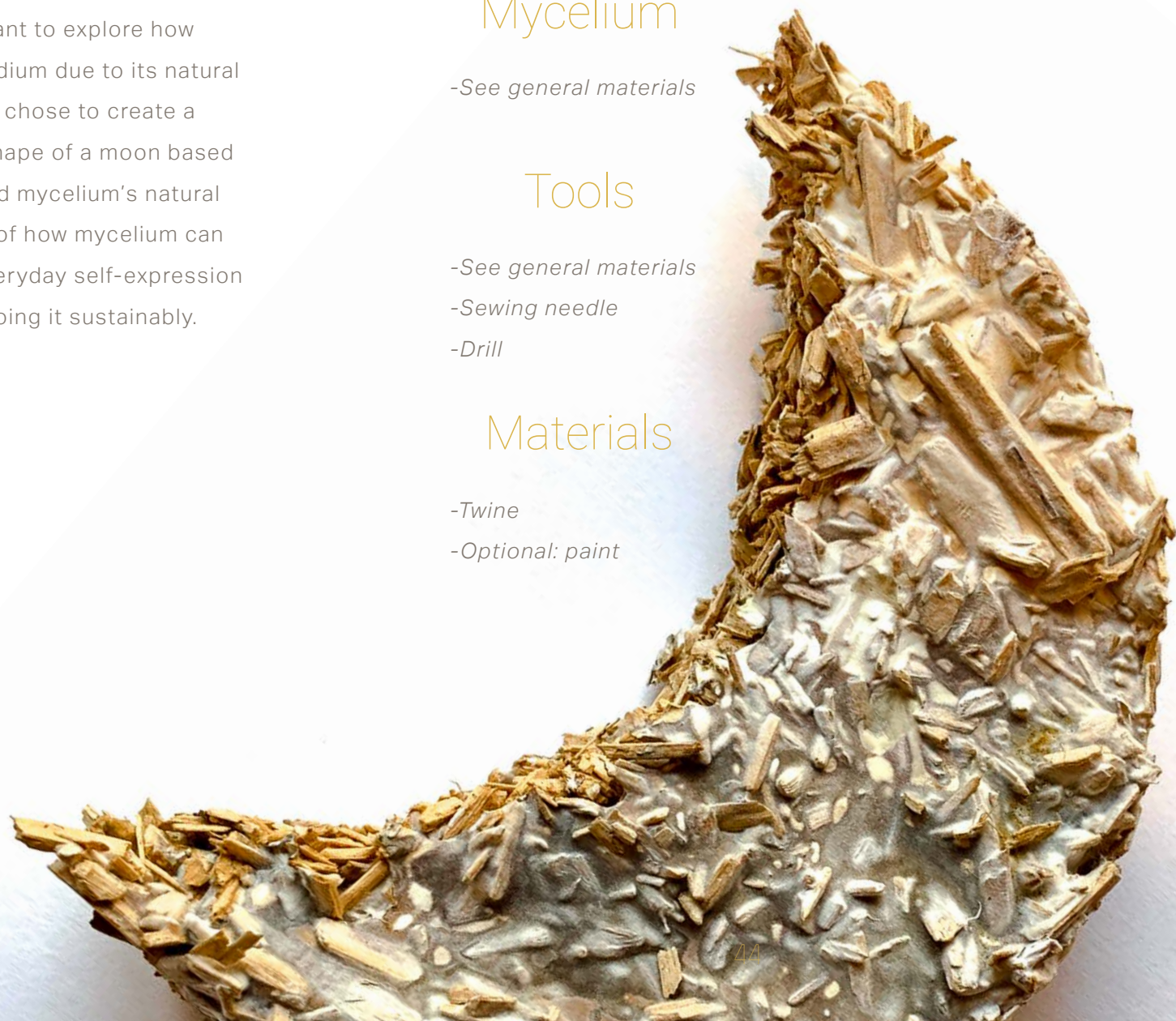
*-See general materials*

## Tools

*-See general materials*
*-Sewing needle*
*-Drill*

## Materials

*-Twine*
*-Optional: paint*



# Method

**Steps one** For the mold, obtain a plastic container with the intended shape of the wall art (in this case, a circular container was used)

**Step two** Primary Growing Process (see general process)

**Step three** Secondary Growing Process (see general process)

**Step four** Baking Process (see general process)

**Final steps** Final Artifact Process

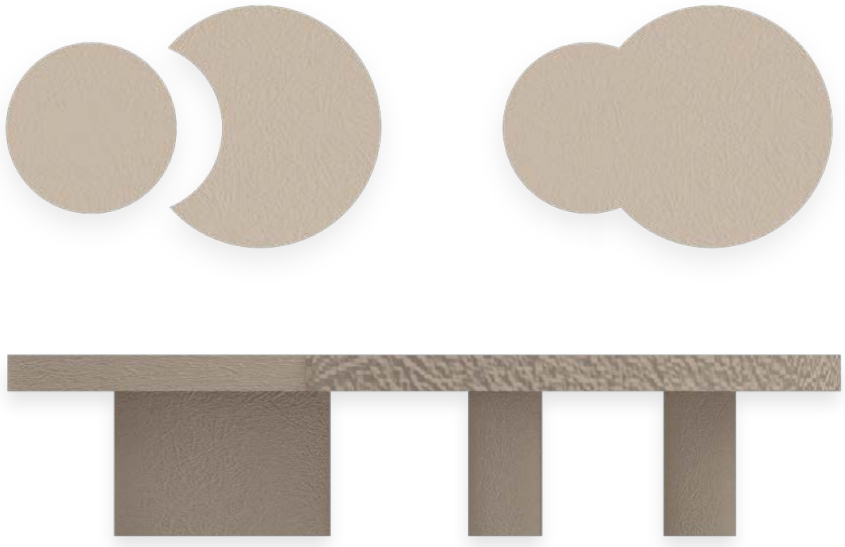
1. Cut into a moon shape using an exacto knife
2. Optional: Paint
3. Drill a hole at the top of the piece
4. Thread twine through the hole, tying it together at the top so it can be hung
5. Decorate with your new moon



# Speculation 1

## Bio Furniture:

## There's Mushroom for Innovation



Theresa Matick



Plastic is one of the most widely used materials in consumer goods because of its favorable qualities for design, low cost, and that it's easy to mass produce. Within a short time of its introduction, plastic had successfully replaced many traditionally used materials, most notably in furniture, as it gave new possibilities for design that did not exist before [31]. Although plastic seemed like the miracle material of the last century, it did not come without consequences. By the 1960s, plastic had already started to become visible in our oceans [13]. Since then, the problem has only worsened, as plastic takes hundreds of years to degrade on its own [16].

Knowing that home goods and furniture have great potential for improvement in sustainable materiality, we chose to seek out

alternative solutions as well as finding ways to make the process of fabricating and assembling furniture easy to understand and affordable. With the help of open source platforms and online communities of fellow DIYers, we were able to gather insight on how to make this happen.

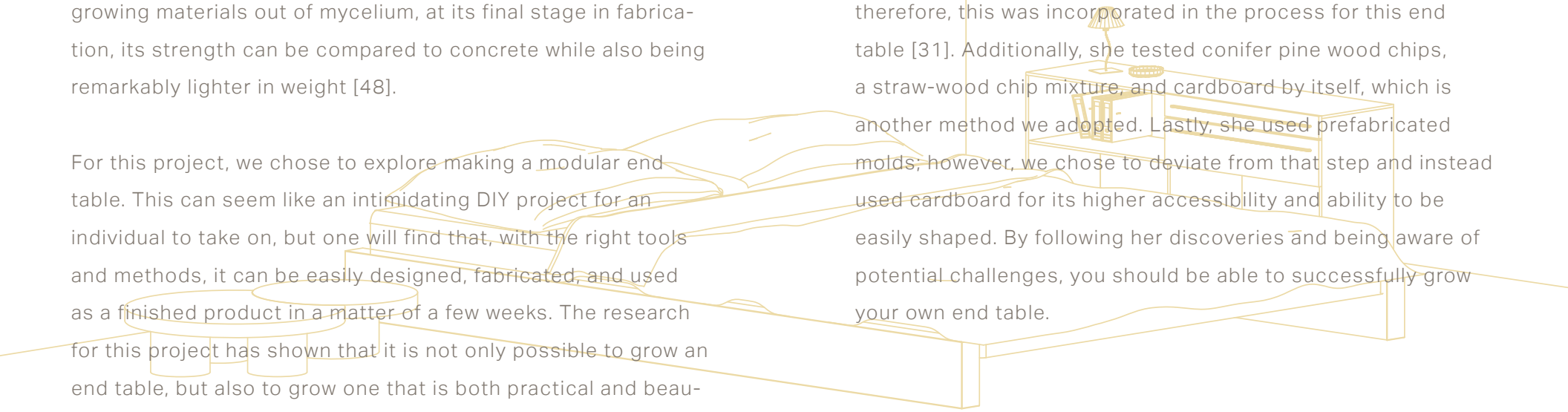
A popular choice for both designers and DIYers alike is mycelium thanks to its plastic-like qualities such as its ability to be easily shaped and sculpted. Mycelium is also flame retardant, water resistant [19] and has the capacity to vary in density and strength based on how it's fabricated. Its biodegradability is a plus as well. On top of all this, mycelium is self-binding and can be grown with almost any substrate, creating a strong, durable material suited for furniture. In fact, Phillip Ross, co-founder of San Francisco based company Myco Works, found that while growing materials out of mycelium, at its final stage in fabrication, its strength can be compared to concrete while also being remarkably lighter in weight [48].

For this project, we chose to explore making a modular end table. This can seem like an intimidating DIY project for an individual to take on, but one will find that, with the right tools and methods, it can be easily designed, fabricated, and used as a finished product in a matter of a few weeks. The research for this project has shown that it is not only possible to grow an end table, but also to grow one that is both practical and beautiful. For example, Dr. Natalia Piorecka, who explored making furniture with mycelium for her dissertation at Newcastle University, successfully created a chair and stool [28].



Accessibility for DIY projects was also important for Piorecka, so she first set out to see the most affordable ways to cultivate mycelium in a home environment. She used two approaches: One using a self-prepared material composite, and the other using a dehydrated mycelium mixture from the company, Ecovative. The final result showed that using the dehydrated mycelium yielded the best results in durability and the ability to grow into complex shapes [31]. This mixture also had a chance of survival of the mycelium, making it best option for affordability and accessibility.

This end table recipe is inspired by her research, where she worked with oyster mushrooms in a dehydrated mycelium mix—much like the other projects' mycelium in this book. She also found that it grew the fastest with hemp and aspen substrates; therefore, this was incorporated in the process for this end table [31]. Additionally, she tested conifer pine wood chips, a straw-wood chip mixture, and cardboard by itself, which is another method we adopted. Lastly, she used prefabricated molds; however, we chose to deviate from that step and instead used cardboard for its higher accessibility and ability to be easily shaped. By following her discoveries and being aware of potential challenges, you should be able to successfully grow your own end table.



## Molds

*-Cardboard*

*-Non-porous tape*

## Tools

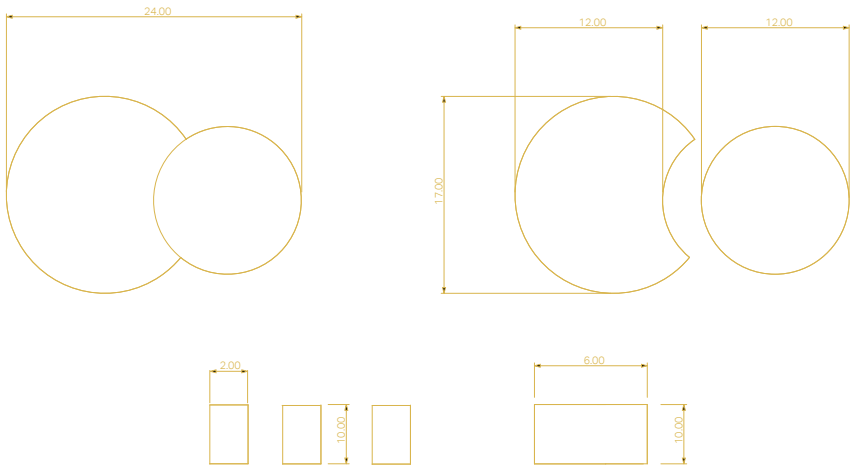
*-See general materials*

## Mycelium

*-See general materials*

## Materials

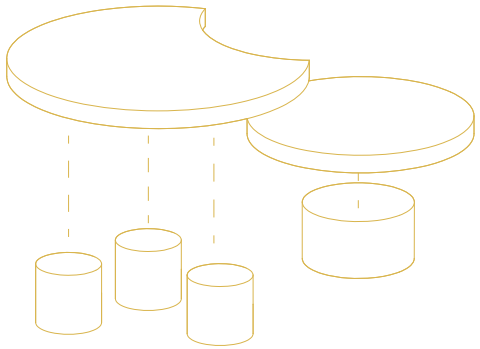
*-Wood glue*




# Method

**Steps one** Mold Creation Process

1. For the mold, allot 6 parts made of cardboard, (2 for table top and 4 for legs)
2. Line cardboard with a non-porous tape, such as packaging tape.



**Step two** Primary Growing Process (see general process)

**Step three** Secondary Growing Process (see general process)

**Strep four** Baking Process (see general process)

**Final Steps** Final Artifact Process

1. Attach legs to each table top using wood glue (three legs to larger table top with half circle cut out and one leg to the smaller circular top)

# Speculation 2

## Hide and Seek:

## Finding A Sustainable Alternative to Leather

Malika Rakhmonova



The bovine beauties that graze on open pastures are hiding a greater cost than what the consumers pay for in their meat and hide. Twenty-eight times more land and eleven times more irrigation water is invested in the upkeep of cattle than any other common livestock [21]. Because of that, the cowhide rug adorning the hardwood of your local furrier's shop is more costly than it seems—at least for the environment. However, mycelium leather has recently emerged as an environmentally friendly alternative to real leather, all without the massive amounts of land and water required for it. Moreover, mycelium is aesthetically versatile and can provide the same eye-catching, luxurious value akin to a genuine cowhide rug.

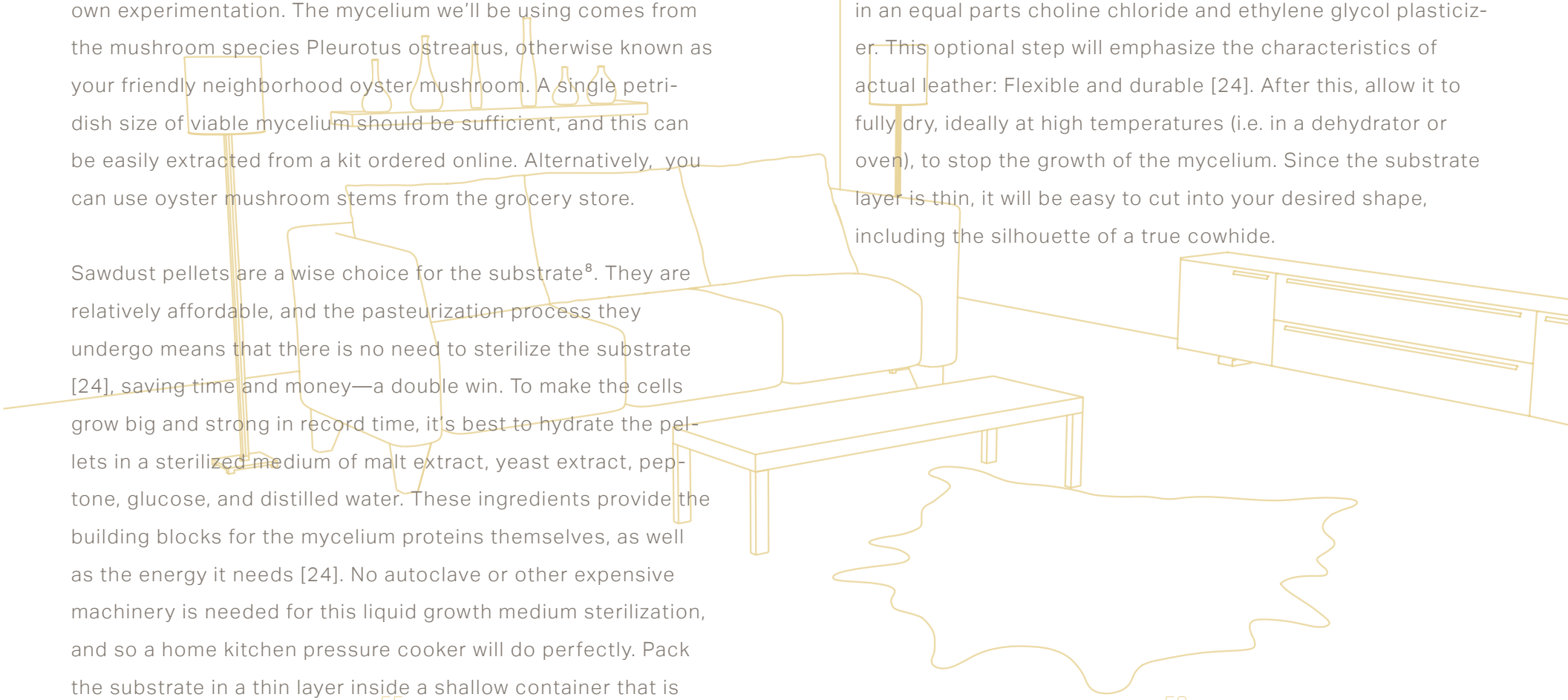
In fact, the concept of utilizing myco-leather for luxurious pur-

poses has been realized before, as showcased by the likes of fashion designer and animal rights activist Stella McCartney, who has debuted a prototype of her Falabella bag made entirely from mycelium leather [29]. Thus, its lux promise has already been proven, and so this section extends that proof through creating our own "cowhide" rug right at home.

The recipe for this speculation draws upon the techniques described by PhD researcher Elise Elsacker at the Vrije Universiteit Brussel via the BioFab forum [24] in combination with our own experimentation. The mycelium we'll be using comes from the mushroom species Pleurotus ostreatus, otherwise known as your friendly neighborhood oyster mushroom. A single petri-dish size of viable mycelium should be sufficient, and this can be easily extracted from a kit ordered online. Alternatively, you can use oyster mushroom stems from the grocery store.

Sawdust pellets are a wise choice for the substrate[8]. They are relatively affordable, and the pasteurization process they undergo means that there is no need to sterilize the substrate [24], saving time and money—a double win. To make the cells grow big and strong in record time, it's best to hydrate the pellets in a sterilized medium of malt extract, yeast extract, peptone, glucose, and distilled water. These ingredients provide the building blocks for the mycelium proteins themselves, as well as the energy it needs [24]. No autoclave or other expensive machinery is needed for this liquid growth medium sterilization, and so a home kitchen pressure cooker will do perfectly. Pack the substrate in a thin layer inside a shallow container that is the desired hide size (preferably transparent as well, so you can watch it grow and maniacally laugh, "it's alive!").

After an ideal period of incubation at slightly above room temperature and in high moisture, the myco-leather will grow at its maximum rate. Oyster mushrooms like to bask in warm and humid environments [24], so this will ensure that the mycelium grow all the way through the substrate as fast as possible. Once this happens, the hide can be harvested. While the hide is still alive and somewhat humid, preserve the flexibility by soaking it in an equal parts choline chloride and ethylene glycol plasticizer. This optional step will emphasize the characteristics of actual leather: Flexible and durable [24]. After this, allow it to fully dry, ideally at high temperatures (i.e. in a dehydrator or oven), to stop the growth of the mycelium. Since the substrate layer is thin, it will be easy to cut into your desired shape, including the silhouette of a true cowhide.



## Molds

*-Transparent plastic or resin container*

## Mycelium

*-See general materials*

## Tools

*-See general materials*

## Materials

*-Ethylene glycol*

*-Choline chloride*

*-Scissors or exacto knife*

## Method

**Steps one** For the mold, obtain a container of desired size

**Step two** Primary Growing Process (see general process)

**Step three** Secondary Growing Process (see general process)

**Final Steps** Final Artifact Process

1. Let the mycelium grow in the molds until molds are completely white
2. Remove mycelium hide from molds and soak in equal parts choline chloride and ethylene glycol plasticizer mixture for 48 hours
3. Gently rinse the hide with distilled water so that all of the plasticizer is removed
4. Remove mycelium from molds and let dry for 1-2 days
5. Cut hide using scissors or exacto knife into the desired shape desired

# Afterword

60

*"In this section, we illustrate a more personal look into the team's journey through our mycelium projects. We also wanted to include a space in the book for us to reflect on our personal Biodesign Challenge experiences, especially in the special circumstances we found ourselves in due to the COVID-19 pandemic during our Spring 2020 semester. The following passages detail some of those unique accounts by our teammates, whom have all persisted, conquered, and grown immensely throughout this project—and for that they should feel great pride. So without further adieu, please enjoy this special afterword, and from the team to you, thank you kindly for joining us on our MyCo Domicilia adventure."*

-F. Ria Khan

*"Students affiliated with STEM (Science, Technology, Engineering, and Mathematics) are always encouraged to innovate and develop new ideas that can improve the quality of human life and enable society to adopt greener practices. The Biodesign Challenge gave me, my teammates, and many other students across the world an opportunity to bridge the gap between art, design, and biotechnology, facilitating a way to come up with solutions to issues in need of fixing. It was an honor to be on the first BDC team at CU Boulder, and it was an enriching experience working with a team of dedicated engineers and biologists, as well as designers and artists in order to develop a vision that we believe and trust. We also had the opportunity to brainstorm and come up with new ideas and were given a lot of creative freedom with our project. As a student in the STEM field, I was given the chance to apply my knowledge but also showcase my abilities in design which was a first for me. Sadly, with the onset of the COVID-19 pandemic, there were certain setbacks that we faced in terms of project development, and I was even unfortunate enough to have contracted the virus myself. Nonetheless, it gave me a chance to adapt to the current remote conditions and formulate a new game plan with my group in order to see the project through to the end. There is nothing more satisfying to me than the fact that we were able to introduce an idea meant to make new strides in sustainability, improve the quality of life of future generations, and in doing so in-spite of the situation at hand. I am confident that BDC will be just as happy with it as we are."*

-Shenali Uragoda



*"Summarizing a project that was this large, alive, and dynamic is no easy task. Its implications for the world exceed my imagination, but at least it is possible for me to explain how it all made me feel. From mycelium contamination to COVID-19, it is no secret that there were persistent hurdles to overcome this semester. Still, my team has confidently come out on the other side, developing a book, website, video, and social media accounts documenting our discoveries in the biodesign sphere. Yet inside, I have gained something more valuable, and that is a newfound sense of pride in the power of a team, as well as a glimpse into my own potential to learn and to create things that will help the world. I will remember the ways I was challenged throughout this semester, and it is important to me to acknowledge the guidance I generously received along the way to help make my mark in the pursuit of sustainable design. So, as a final note, I take what I learned during the Biodesign Challenge, bring it back to my community, and hope to pave a path for others to also make their mark on the quest for a greener and happier Earth."*

-Malika Rakhmonova

*"As one of the two graduate members of the team, I felt it was my duty to not only lead, mentor, and teach, but to also shoulder any extra lab-related work needed for a successful project. This being said, when COVID-19 hit, I happily volunteered to take the mycelium and necessary equipment home with me, and essentially turning my bedroom into an unofficial bio-lab. Little did I know that by taking on this task, I was leading myself down*

*a rabbit hole of obsession. Like many people have during their quarantine, learning new hobbies have been a healthy way to cope while spending the extra free time at home. However, unlike those who were baking banana bread or learning tik tok dances, my method of coping with these unknown times was growing the mycelium and designing products from it. This was great until it wasn't. A few weeks in, much of the mycelium stored in my home became contaminated with mold, and I deeply began to worry for the rest of the cultures. This even culminated to a few days where I wasn't able to get a full night's sleep because I was having nightmares about killing all the mycelium. Seriously. This experience, while difficult at the time, quickly put my life into perspective and made me realize that my quarantine hobby was getting a bit out of hand. Thankfully, my kind and supportive team grounded my fears, allowing me to look back on my experience and laugh about how silly a role mycelium played in my life during these crazy times."*

-Fiona Bell

*"The Biodesign Challenge allowed me to be in an environment where, for the first time, I was able to work in a multidisciplinary team in the context of design. This enriching experience allowed me to see the value of embracing multiple inputs toward the same goal. My background is scenic and product design, so I was especially excited to learn more about biology, scientific methods of documentation, and how working in a lab would be like. Also, I have always been interested in working with biobased materials in the context of product design and*



*artistic expression for the purpose of exploring what's possible and challenging our assumptions of what we classify as art, science, and design. This project allowed me to dive deeper into this exploration by observing the artifacts in our project—the website, book, video and social media accounts—all come together to highlight the multifaceted world of mycelium. Due to COVID-19, I was not able to successfully grow my own mycelium project in the lab, which is why I took on the more speculative approach. Still, this project opened my eyes to a new perspective on the products I use daily and how I can improve upon them in both materiality and design. I'm excited to apply what I learned during this project to my future investigations and discoveries. I also look forward to using this recipe book to see my speculative project through."*

-Theresa Matick

# Discussion Questions

These questions were conducted for our team to reflect on and answer in order to extend the reader's understanding of our progress and motivations for this project. The following answers are a curation of the team's individual responses.

**What were the team's initial expectations and reaction to mycelium as a material?**

*Prior to this project, most of us hadn't heard of mycelium. We were intimidated by its unpredictability and whether or not it could be kept alive since our entire project was dependent on it. Ultimately however, after much research, we realized the versatility of mycelium and were all undeniably excited to work with it as a material for everyday objects.*

**What kind of affordances does mycelium have and how did it motivate the team's intrigue to work with the material?**

*Mycelium is biobased and biodegradable. Its sustainability factor is what our team was initially motivated by; however, we were truly inspired by its physical properties that make it ideal for everyday products. It's lightweight, strong, durable, thermally resistant, hydrophobic, and fire retardant. Mycelium is also affordable, shapeable, and grows relatively quickly, making it an ideal material for DIY projects like our own.*



**What were some key reasons as to using mycelium for the purposes of creating domestic/everyday things?**

*Since mycelium is a natural material that is sustainable, environmentally friendly, and cost efficient, it seemed like a no-brainer to try and utilize these properties to make something that anyone can have access to. We as a society could make a huge difference by simply exchanging the materials we see in everyday life like: Plastic, concrete, foam, and wood for more sustainable materials like mycelium. On top of that, the idea of making everyday things in the comfort of one's own home is exciting and evokes fun in practicing sustainability.*

**Were there obstacles that you faced during the project? How did the team overcome these, individually or together?**

*Mycelium, being a living material, requires a specific set of conditions to grow, including moisture and temperature. Working in the dry climate of Colorado meant that often the material would not grow. We also faced the obstacle of COVID-19. This initially impeded our project due to our lab space, where we were housing the mycelium, being shut down. In order to overcome these obstacles, we developed the speculation section, so that mycelium's true versatility was not truncated and that we could still showcase what is really possible. We also made mini home labs, and continually checked up on each other's progress via the Slack and Zoom app.*

Looking back on the recipes, what are insights the team has gained?

*Given the fact that none of our team had any experience growing mycelium, we all had to learn (and fail) a lot to make successful products. One of our first challenges was deciding on a growth medium. We tried everything from coffee grounds to cardboard and finally decided to use a pre-sterilized mix of wood chips, hemp, and flour. We also struggled with finding a balance between under and over-sterilization, as many projects failed along the way due to mold contamination or non-viable mycelium tissue. However, all of this struggle gave us more resolve in creating our DIY recipe book—to help those who are inexperienced, like we initially were, create their own mycelium projects with ease.*

For speculative works, what were the most difficult aspects of creating speculations for mycelium recipes? The most fun?

*It was challenging to put ourselves in the shoes of someone who would be attempting our project recipes and to sequence instructions for them in such a way that was justified and clear enough to execute. Additionally, it was difficult to grasp the potential behaviors of the material at first. Yet, despite this challenge, we gleaned the most fun and motivation from thinking about all of the possibilities of mycelium once we did more research. Seeing that something similar had been successfully done before was not only encouraging but also helped guide us in the speculative process. Overall, because of this exploration, conceiving these recipes was more engaging than difficult in the end.*

How has the team's perspective changed on the medium? What was something unexpected? What was something that is now appreciated?

*Like anything in life, growing mycelium has a learning curve. However, what was unexpected was the struggle to find any documented failures in this fabrication process while our own explorations were far from straight-forward, leaving us with some discouragement. But once we learned what the mycelium liked to grow in, what conditions it thrives in, and sterilization protocols for living organisms, it was not that hard. This was especially exciting when we were able to find success in our project's endeavors, and we feel proud! Due to the unexpected challenges of COVID-19, our team looks back on our semester and appreciates the significance of in-person time spent brainstorming and workshopping our ideas. This early planning facilitated the freedom for our teammates to express their passions from fashion to toy-making, while all unified under the single concept of: MyCo Domicilia, everyday objects made from mycelium for accessibility and sustainability.*

# Index

**Biobased**[1]- A material or product that is composed of biological products or renewable domestic agricultural materials (including plant, animal, and marine derived materials) [17].

**Biodegradable**[2]- Organic matter that has the capacity to be broken down by microorganisms, such as bacteria and fungi [24].

**Fabrication**[3]- The act or process of fabricating; to manufacture; to make [9].

**Incubator**[4]- An enclosed container or technical equipment used to grow microorganisms under controlled conditions [31].

**Medium**[5]- Also known as growth medium, a solid or liquid on which cells can grow [33].

**Mycelium**[6]- The vegetative structure for fungi that produce mushrooms; the root system of mushrooms [2].

**Sterilize**[7]- To make (something) free of bacteria or other living microorganisms [41].

**Substrate**[8]- The surface or material on or from which an organism lives in, grows in, and/or receives nourishment [42].



# References


[1] 5 Toxic Craft Supplies: https://ecofriendlycrafts.com/blogs/green-crafting/5-toxic-craft-supplies. Accessed: 2020-05-13.

[2] 5 Truths the Fast Fashion Industry Doesn't Want You to Know: 2014. https://www.huffpost.com/entry/5-truths-the-fast-fashion_b_5690575. Accessed: 2020-05-13.

[3] AlgiKnit: https://www.algiknit.com. Accessed: 2020-05-13.

[4] Because You Asked: Can You Recycle 3D-Printed Objects? https://livegreen.recyclebank.com/column/because-you-asked/can-you-recycle-3d-printed-objects. Accessed: 2020-05-13.

[5] Chemists develop fully biodegradable and recyclable synthetic resin: https://www.sciencedaily.com/releases/2011/01/110113082625.htm. Accessed: 2020-05-13.

[6] Crosby, W. What is Mycelium: Nature's World Wide Web Underneath Our Feet. Fungi Ally.

[7] Definition of fabrication | Dictionary.com: https://www.dictionary.com/browse/fabrication. Accessed: 2020-05-21.

[8] Definition of Tetrahedron: https://www.mathsisfun.com/definitions/tetrahedron.html. Accessed: 2020-05-13.

[9] Environmental Hazards of Leather: 2010. https://www.peta.org/issues/animals-used-for-clothing/leather-industry/leather-environmental-hazards/. Accessed: 2020-05-13.

[10] First Clothes Made From Bioplastics: 2019. https://bioplasticsnews.com/2019/07/08/first-clothes-made-from-bio

plastics/. Accessed: 2020-05-13.

[11] Ghazvinian, A., Farrokhsiar, P., Vieira, F., Pecchia, J. and Gursoy, B. 2019. Mycelium-Based Bio-Composites For Architecture: Assessing the Effects of Cultivation Factors on Compressive Strength. Blucher Design Proceedings (Porto, Portugal, Dec. 2019), 505–514.

[12] Hemmings, J. 2008. Grown Fashion: Animal, Vegetable or Plastic? TEXTILE. 6, 3 (Nov. 2008), 262–273. DOI:https://doi.org/10.2752/175183508X377627.

[13] History and Future of Plastics: 2016. https://www.sciencehistory.org/the-history-and-future-of-plastics. Accessed: 2020-05-13.

[14] Home: https://grow.bio/. Accessed: 2020-05-13.

[15] Home | MyCo Domicilia | BDC2020: https://myco-domicilia.wixsite.com/forbdc2020. Accessed: 2020-05-21.

[16] How Long Will It Take That Bag of Trash to Decompose in a Landfill? https://www.thebalancesmb.com/how-long-does-it-take-garbage-to-decompose-2878033. Accessed: 2020-05-13.

[17] Incubator | Definition of Incubator by Lexico: https://www.lexico.com/en/definition/incubator. Accessed: 2020-05-14.

[18] Jones, M., Bhat, T., Kandare, E., Thomas, A., Joseph, P., Dekiwadia, C., Yuen, R., John, S., Ma, J. and Wang, C.-H. 2018. Thermal Degradation and Fire Properties of Fungal Mycelium and Mycelium - Biomass Composite Materials. Scientific Reports. 8, 1 (Dec. 2018), 17583. DOI:https://doi.org/10.1038/s41598-018-36032-9.

[19] Jones, M., Mautner, A., Luenco, S., Bismarck, A. and John, S. 2020. Engineered mycelium composite construction



materials from fungal biorefineries: A critical review. Materials & Design. 187, (Feb. 2020), 108397. DOI:https://doi.org/10.1016/j.matdes.2019.108397.

[20] Magnetic Tetra-Bricks! by QuantumZ: https://www.thingiverse.com/thing:2812880. Accessed: 2020-05-13.

[21] McGrath, M. 2014. Beef's greater environment burden. BBC News.

[22] medium - Terminology of Molecular Biology for medium – GenScript: https://www.genscript.com/molecular-biology-glossary/1815/medium. Accessed: 2020-05-14.

[23] Metal vs. plastic vs. glass vs. ceramic: Which is the best phone material? 2019. https://www.androidcentral.com/metal-vs-plastic-vs-glass-which-best-material-phones. Accessed: 2020-05-13.

[24] Method of making mycelium-leather: 2018. https://biofabforum.org/t/method-of-making-mycelium-leather/218. Accessed: 2020-05-13.

[25] Mushroom leather / Muskin - Everything you need to know! https://danandmez.com/blog/mushroom-leather/. Accessed: 2020-05-13.

[26] MyCo Domicilia (@myco_domicilia) • Instagram photos and videos: https://www.instagram.com/myco_domicilia/. Accessed: 2020-05-14.

[27] MyCo Domicilia (@Myco_Domicilia) / Twitter: https://twitter.com/myco_domicilia. Accessed: 2020-05-21.

[28] MYCOsella - Growing the Mycelium Chair: https://issuu.com/nataliapiorecka/docs/dissertation_project_ba_architectur. Accessed: 2020-05-13.

[29] MyloTM | Vegan, Sustainable Mycelium Leather: 2018.

http://boltthreads.com/technology/mylo/. Accessed: 2020-05-13.

[30] Pinterest: https://www.pinterest.com/. Accessed: 2020-05-13.

[31] Plastic - the mouldable material of modern chairs: https://www.architonic.com/en/story/susanne-fritz-plastic-the-mouldable-material-of-modern-chairs/7000634. Accessed: 2020-05-13.

[32] Sanchez-Garcia, M.D., Lopez-Rubio, A. and Lagaron, J.M. 2010. Natural micro and nanobiocomposites with enhanced barrier properties and novel functionalities for food biopackaging applications. Trends in Food Science & Technology. 21, 11 (Nov. 2010), 528–536. DOI:https://doi.org/10.1016/j.tifs.2010.07.008.

[33] Scientists create new building material out of fungus, rice and glass: http://theconversation.com/scientists-create-new-building-material-out-of-fungus-rice-and-glass-98153. Accessed: 2020-05-14.

[34] Sterilize | Definition of Sterilize by Lexico: https://www.lexico.com/en/definition/sterilize. Accessed: 2020-05-14.

[35] Substrate | Meaning of Substrate by Lexico: https://www.lexico.com/definition/substrate. Accessed: 2020-05-14.

[36] Terry, B. 2018. The Little Teapot That Could. TeaTime Magazine.

[37] The Aesthetic Movement Overview: https://www.theartstory.org/movement/aesthetic-art/. Accessed: 2020-05-13.The

[38] New Plastics Economy: Rethinking the future of plastics: https://www.ellenmacarthurfoundation.org/publications/the-new-plastics-economy-rethinking-the-future-of-plastics. Accessed: 2020-05-13.

[39] The Ultimate Battle of Phone Case Materials, and the Winner is...: https://www.ipitaka.com/blogs/news/the-ultimate-battle-of-phone-case-materials-and-the-winner-is. Accessed: 2020-05-13.

[40] V&A · Ceramics: https://www.vam.ac.uk/collections/ceramics. Accessed: 2020-05-13.

[41] Vasquez, E.S.L. and Vega, K. 2019. Myco-accessories: sustainable wearables with biodegradable materials. Proceedings of the 23rd International Symposium on Wearable Computers (London, United Kingdom, Sep. 2019), 306–311.

[42] Vollebak's plant and algae T-shirt becomes "worm food" in 12 weeks: 2019. https://www.dezeen.com/2019/08/28/vollebak-plant-and-algae-t-shirt-sustainable-biodegradable-fashion/. Accessed: 2020-05-13.

[43] Yours for the making: https://www.instructables.com/. Accessed: 2020-05-13.

[44] 2017. Biobased product. Wikipedia.

[45] 2019. Biodegradable Materials: Design and Architecture. IA Interior Architects.

[46] 2020. Biodegradation. Wikipedia.

[47] 2018. Building with Mushrooms | | Critical Concrete.

[48] Philip Ross Molds Fast-Growing Fungi Into Mushroom Building Bricks That Are Stronger than Concrete.

# Acknowledgments

Book Editor, Designer/Photo Editor/Web Developer- F. Ria Khan

Co-Web Developer and Mobile Web Developer - Arva Syed

Photographer/Mycelium Keeper - Fiona Bell

Book Illustrator- Theresa Matick

# The Team

**Fiona Bell**
First year graduate student at the ATLAS Institute in CU with a background in mechanical engineering. Her interests lay in creating beautiful, functional, and sustainable products that bring value and joy to the world.

**Farjana Ria Khan**
Masters student and researcher from the ATLAS Institute. Their research is in Human Computer Interaction where they express their passions by exploring the intersections between fine art, critical design, tech, and gamified interaction.

**Theresa Matick**
Undergrad in the Environmental Design Program at CU. She is passionate about using design as a vehicle to explore the relationships between the natural environment and advancing technology, with a focus on experiential and product design.

**Malika Rakhmonova**
Undergrad in the biochemistry program at CU. A self proclaimed chef, her interest in biotechnology is fueled by environmental sustainability efforts and bettering the lives of human beings — one mushroom at a time.

**Arva Syed**
Third year undergrad in the ATLAS Institute and Biomedical Engineering program at CU Boulder. She hopes to be a product designer for bio medical technology and improve people's quality of life.

**Shenali Uragoda**
Junior Undergrad in Biochemistry program. She is currently developing biochips that utilize the mechanism of bacteriophages as a more cost efficient and accessible method of phage therapy.

# The Instructor

**Mirela Alistar PhD**
Assistant professor for the ATLAS Institute as well as the Computer Science Department at CU Boulder. She investigates the extent to which we can change healthcare to make it a personal process. Her research focuses around microfluidic biochips, devices that enable direct interaction of humans with their microbiome for diagnosis purposes. So far, Mirela has built systems based on biochips to serve as personal laboratories: small portable devices that people can own and use to develop customized bio-protocols ("bio-apps").