The Art of Microbe Maintenance: Value and Applications in Design

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The Art of Microbe Maintenance: Value and Applications in Design

by Yujin Hwang

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A thesis presented in partial fulfillment of the requirements for the degree Master of Industrial Design of the Rhode Island School of Design, Providence, Rhode Island.

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STARING AT THE WAVES

I wake up in the morning and look out the window. It seems a little bit chilly, but a nice day for a run. When I run, I feel good. This is one of the exercises I have been enjoying recently. I change my clothes, put on my shoes, leave the house, and start to run along Hope Street. I ran to India Point Park. It is my favorite running path. I feel fresh. Especially when I feel stuffy when I'm stuck inside, running helps me to get over that feeling. Today is that day.

India Point Park is beautiful, as always. I stop in front of the water for a while to stare at the waves. The waves are reflecting the sunlight, moving gently. It seems like somebody sprayed tons of stars on the water. The waves are twinkling, just like diamonds. I am staying longer than usual. Maybe it is because I need more time to relax, think and feel nature. I close my eyes. I think about the people I miss a lot and breathe the air. I feel like I can see, smell, and hear them. The wind touches me; it is cold, but warm.

I open my eyes again. The water is blue. But the color changes everyday, and all the time. It reflects the color of the sky. It is clean today. Sky color depends on how much sunlight enters the atmosphere. How wonderful that everything is connected? Sunlight, sky, water and me standing in front of them.

Things around us are all affecting each other. They never exist by themselves. They influence us too, like we affect them. We should treat them rightly to preserve nature. How can we keep their beauty to also make us happy?

ABSTRACT

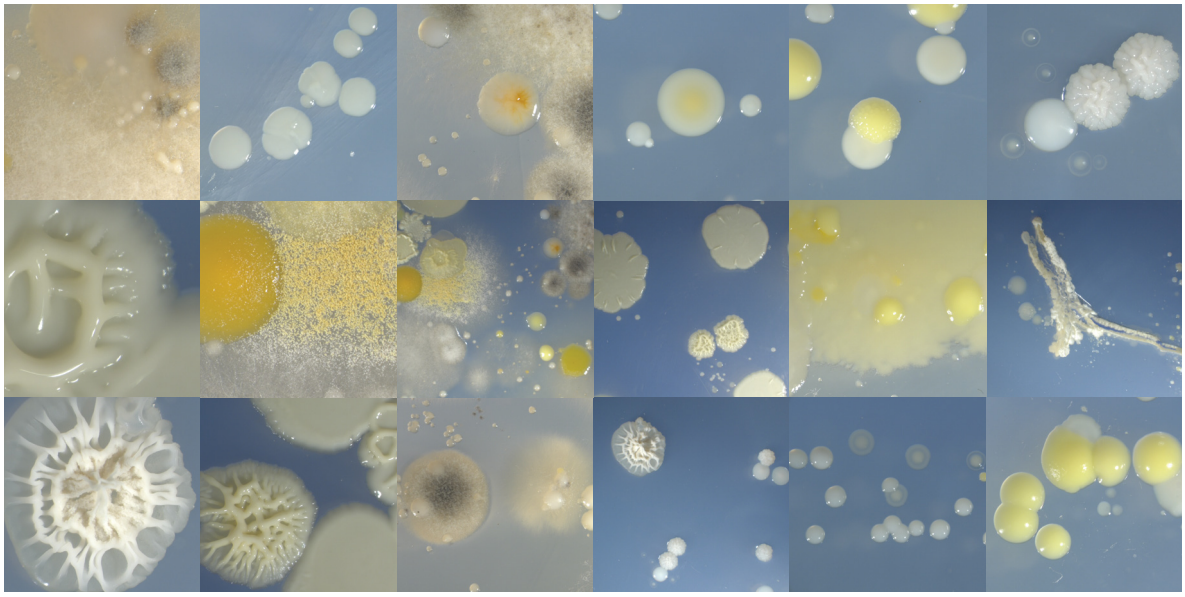
My thesis centers around designing microbial systems and objects for a sustainable future. I propose ideas to bring microbes into the home in order to make people understand them as a part of the environment. Through deep consideration of how my microbe based material could change across national and social contexts, I create accessible, attractive and friendly-looking design objects with microbes that address people's fear of microbial life. I strive to facilitate the intersection and interaction between people and technologies in ways that are ultimately harmonious for the well being of both.

My ultimate goal for my thesis is not only making this material useful, but also finding design processes that could contribute to the environment by returning the design to nature. Furthermore, I would like to implement technologies into this sustainable material so I can suggest ways that designers can use it for various purposes and mass production.

MATERIAL STUDY WITH BACTERIA

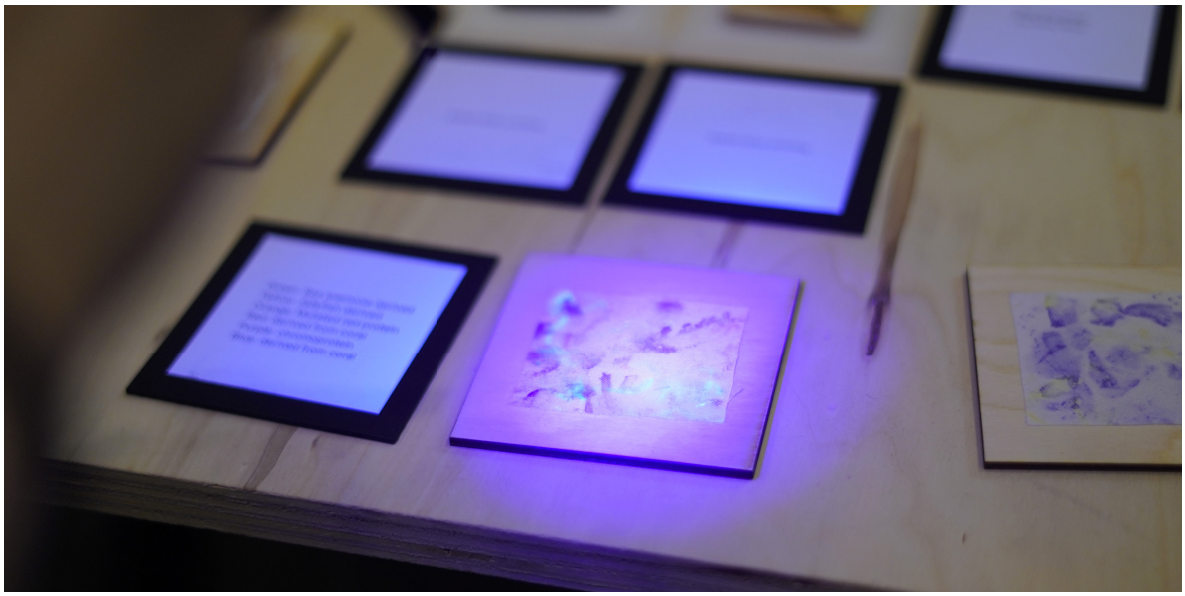

Rose : Kocuria roseus
Pink-red : Serratia marcescens
Yellow : Kocuria rhizophila
Orange : Sarcina aurantiaca
Material information is on the back.
Green: Sea anemone derived
Yellow: Jellyfish derived
Orange: Mutated red protein
Red: derived from coral
Purple: chromeprotein
Blue: derived from coral
Boiled after printing

In 2019, I worked on a project which is called, Material Experiment with Pigment Producing Bacteria. Through this experiment, I wanted to find ways for designers to reduce the harmful manufacturing process and show people how bacteria—normally considered a toxic resource—might contribute to the visual culture. I grew ten kinds of pigment-producing bacteria at the RISD nature lab which I used to color four different kinds of wood and fabric. This project articulates science's role in supporting sustainable design materials and influencing future design thinking practices, and my thesis subject is extension of this work. It also helped shape my perception on design and how it can contribute to the world by using different materials and resources.



Class mates' bacteria

Experiments process



RISD Museum Exhibition 2019

DESIGN MANIFESTO

Design needs to be sustainable. Designers need to think carefully when we release our design to the world. Sustainability for design can be defined in many different ways. It could be sustainably kept by using environmentally-friendly materials, mimicking nature, reducing the harmful process like using toxins or carcinogens to make it effective, recycling, or timeless.

Design should not be simple. Design needs to consist of many different factors. It might reflect the society, politics, economy, environmental problems, or other trends. We need to consider our surroundings and make them coincide with the design that we are doing. Without those considerations, the design cannot have any impact. At the intersection above factors, we have to contemplate and develop to go forward and influence people. Design is not just a decoration, so design fails without consideration and it is best when there is consideration.

Design is not for designers. It ıs easy to be obsessed with only the designers' thoughts or perspectives when we make something feasible. But, we should not overlook other people's views and opinions on that. We must not forget our design can be evaluated by anyone and we are not designing this only for 1% of people in this world. Before we design things, we should not be afraid of getting advice or feedback from other people who are not in this field and that is one of the most vital parts of the design process if we materialize and release them to the market. Design speaks when it is evaluated by people.

Design can help and move people. Design can be useful for people who do not have certain abilities. Design can help children in third world countries. Design can make humans healthy. There's a lot of infinite possibilities that Industrial Design can do for humanity and the world. We, as designers, need to keep finding those opportunities and trying to help them for better living together.

VALUE PROCESS AND APPROACH

I wanted to deliver the idea of: Creating accessible/attractive/friendly-looking designed objects with microbes while addressing peoples' fear of bacterial life. For better comprehension, I began by investigating how microbes could be used in human life in many different ways. From looking into how they shape the world, I found that they could be used as food resources, helping human health, material source and generating energy. From there, I focused on what designers can do with them, and decided to find opportunities by merging biotechnology with industrial design for sustainable environments and humans. I thought that if I design objects which center on microbes, people will feel more comfortable about using microbes for better lives.

In terms of allowing users to interact with daily objects and increasing positive feelings about microbes, I choose to design things that are existing in our home like furniture or electronic products. After interviewing people and the presentation, I realized that building relationships between microbes and people and how they could be useful, will be the most important part in my project.

After working on artifacts with different kinds of microbes, I decided to work with one of the microbe based materials, mycelium. I decided to design a stool and speaker with mycelium to blend them into our interior space. Broadening the ideas, gathering them and fabricating are the most valuable things that I needed to do.

PRECEDENTS

Selfmade by Christina Agapakis and Sissel Tolaas

Self-made is a cheese making project done by Christina Agapakis and Sissel Tolaas.
Different kinds of cheeses are made with different celebrities' bacteria in their body. The project aims to show people how living organisms that exist in the body can also affect the food we consume, and vice versa. When I first saw this project, it gave me the first idea for my thesis in terms of thinking about the relationship between microbes and the human body. It helped me to overcome a cultural fear of microorganisms as well. Before, I had not thought about microbes existing around us that will affect and effect the human body.

Like Agapakis and Tolaas showed us, bacteria we have could be the food resource and we ourselves have the ability to create that bacteria. Normally, microbes are considered as unclean things or harmful. It's true that some bacteria can be bad for us but it's
important to know that the human body actually depends on some types of bacteria, to help us digest food and extract nutrients from it. Without those, our immune system will collapse and people will get ill. But, today, we are trying to get rid of them by sanitizing and keeping things super clean to not get the viruses. So, it is a contradiction. The truth is, we need to coexist with microbes for healthy living. Imagine when there are no microbes in the world after consuming them all, what the future will look like? People will start to find ways to consume microbes intentionally.

Tattoo inks for health tracking by MIT Media Lab

MIT researchers developed a method for replacing tattoo inks with biosensors.They developed four of them and they are reacting to biochemical information in people's bodies and changing colors. They are showing us the new way of health tracking systems in the future. We are not wearing products or putting digital chips in our body any more, we are just having color-changing tattoos on our skin and interacting with them. Technology like this could become a revolutionary new way to monitor health.

This is just a concept of an idea that is applied to pig skin now, so it will take some time to make it practical. But it made me think about technological advances and helped me to imagine possibilities of using microbes, to help people in different ways in the future. I'm not a huge fan of using a lot of technological devices, so the idea of having tattoos on my body seems like a cool and simple solution. While I was researching this project, I was
imagining - what if we put living pigment producing bacteria in our body as well. Their colors could be changed depending on the temperature, humidity or any other environmental factors. I would explore more about the link between environment and
bacteria colors, and find the way we can interact with them safely. If those bacteria can react to our health and show us with their pigments, we will know what kind of bacteria we need to keep our lives healthy.

Biomimicry in Architecture by Michael Pawlyn

In his book, he explains how architects can build a new world of sustainable beauty by learning from nature. He says, "We urgently need to look at means to be regenerative which is to get into a positive cycle in which everything we do we're trying to have a positive impact – in terms of restoring ecosystems, taking carbon out of the atmosphere, regarding communities and so on." I agree on his belief about regenerative design – the development of restorative and renewable systems where output is always greater than input, and beneficial for humans and other species. Functional solutions can be found from biomimicry. I also believe that we can find ways to translate adaptations in biology.

These days, because I am thinking about relationships between nature and human wellbeing, I try to find form factors that become integrated with natural systems. Michael Pawlyn inspired me to look deeper into the world filled with biologically meaningful nature. Especially in chapter 2, he explains how the manufacturing process could be more effective and sustainable. I was in the mass production industry for 5 years, but we hardly considered using the right elements and putting them together in the right way. Even though we can find structural solutions from nature, we do not carefully look into them and waste material resources. Like using all elements in the periodic table instead of using a limited subset of non-toxic materials. For my thesis, I will also look into the ways I can release my design into the world in a sustainable way.

Fungi mutarium by LIVIN studio

Fungi mutarium is developed to turn plastic waste into safe, edible mushrooms. It is a device that can grow plastic eating mushrooms at home. The researchers designed this product to find a way to solve the serious plastic problem we are having in this world. Thinking about growing and feeding mushrooms for the environment and using them as food resources is a new supply system.

Usually, I assume that even though people have incredible ideas based on scientific research and knowledge, sometimes it is hard to reflect the idea into an object or design while considering the whole system at the same time. In that aspect, this project nicely showed people how the problem we have right now could be solved, not only by building the sustainable chain, but also by making an actual product. In my thesis, as well, I am thinking about designing the microbes consuming system and objects for the future. To make sense and be interesting, I would carefully look into the future problems we will face (microbe deficiency), define our needs (what kinds of microbes we will need), and connect them with my ideas to create a sustainable system. What kind of products will we need to solve these problems and how will those products help people to consume microbes?

Neri Oxman - Silk Pavilion

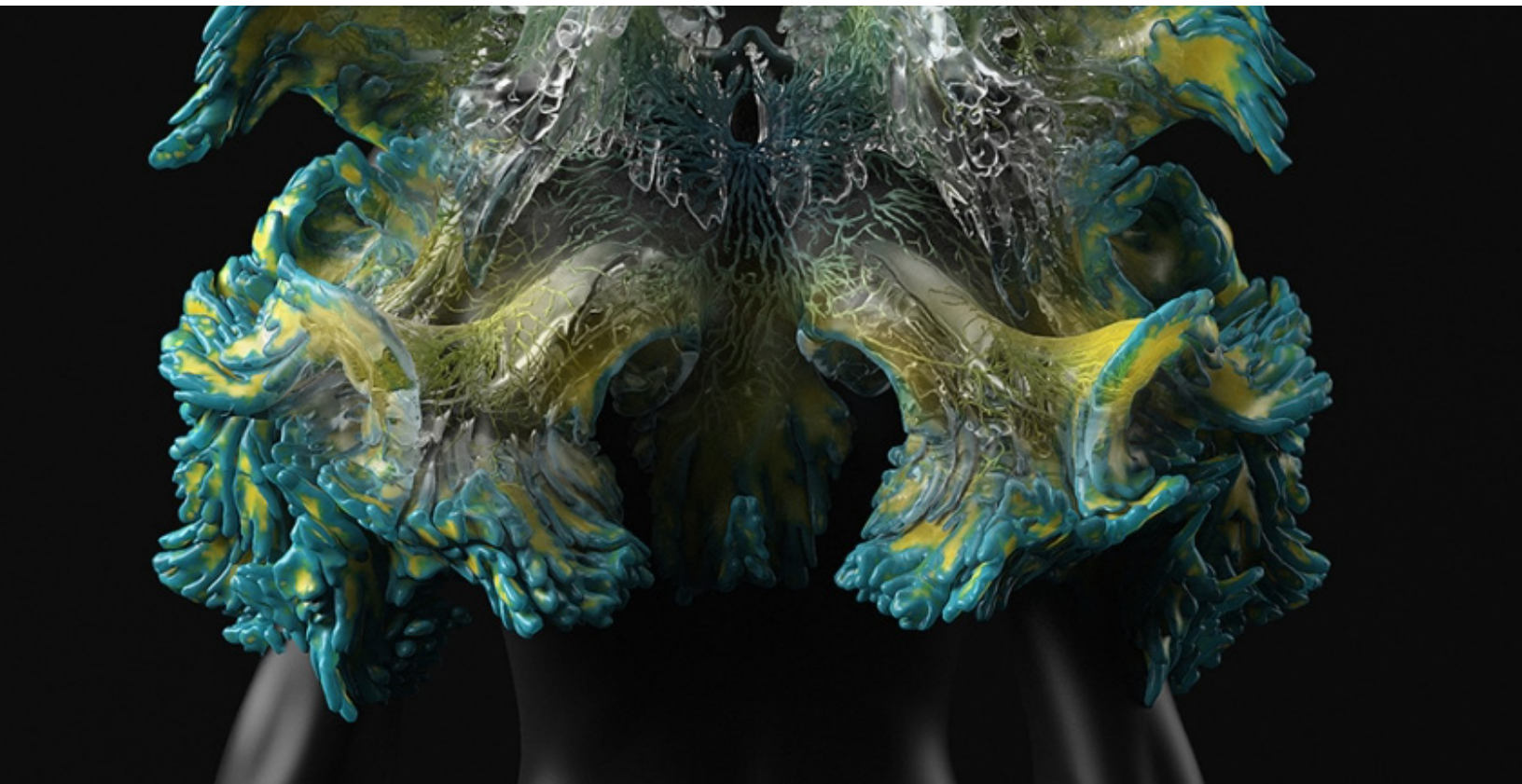
Neri Oxman's design approach inspires me a lot. Her work is always meaningful. I'm always thinking that designers should be responsible for what they release into the world, and she is one of the designers who perfectly shows that in her work. She enables the mediation between objects and environment; between humans and objects; and between humans and the environment.
Not only thinking about material efficiency, her research for environmental performance integration is always interesting.
Her belief of objects, environment, and humans are always linking and affecting each other. It reminds me to think about sustainability as a designer.

Especially the *Silk Pavilion*, designed by the movement of silkworms, it shows us how nature around us can create the structure that we're trying to design naturally. When I saw how this small insect acts, not only as a construction worker but also a designer, I was surprised by its greatness. Natural resources are more powerful than we think, and we can learn from them or find ways to use them. When we design, we are trying to find the
answers from other designed objects or people, not from the nature around us. This project taught me in terms of thinking about how supernatural things around us, could be used for sustainable development and design.

WANDERERS - Neri Oxman in collaboration The Mediated Matter Group, Christoph Bader and Dominik Kolb, in collaboration with STRATASYS

Wanderers is a collaborative project between Neri Oxman and the team at the Mediated Matter Group at MIT Media Lab, with Christoph Bader and Dominik Kolb to realize four digitally grown and 3D printed wearables. Inspired by nature, their idea is that wearables in the future are interacting with specific environments and generating bio-energies that we need for sustaining life. My thesis subject that microorganisms will help people in the future for surviving has a connection with this project.

This project seems very futuristic and revolutionary, but because of its supporting scientific background and exploration, it makes me feel realistic rather than futuristic. Their design research meets the intersection with multi-material 3D printing technology and Synthetic Biology. These days, I am particularly interested in merging biotechnology with industrial design for sustainable environment and human lives. I realize that when art and science meet together perfectly, that gives a sense of wonderment. Thinking about how to put them properly into my design and make it approachable, is what I am contemplating a lot for my design works.



APPLICATION 1,
MYCELIUM STOOL

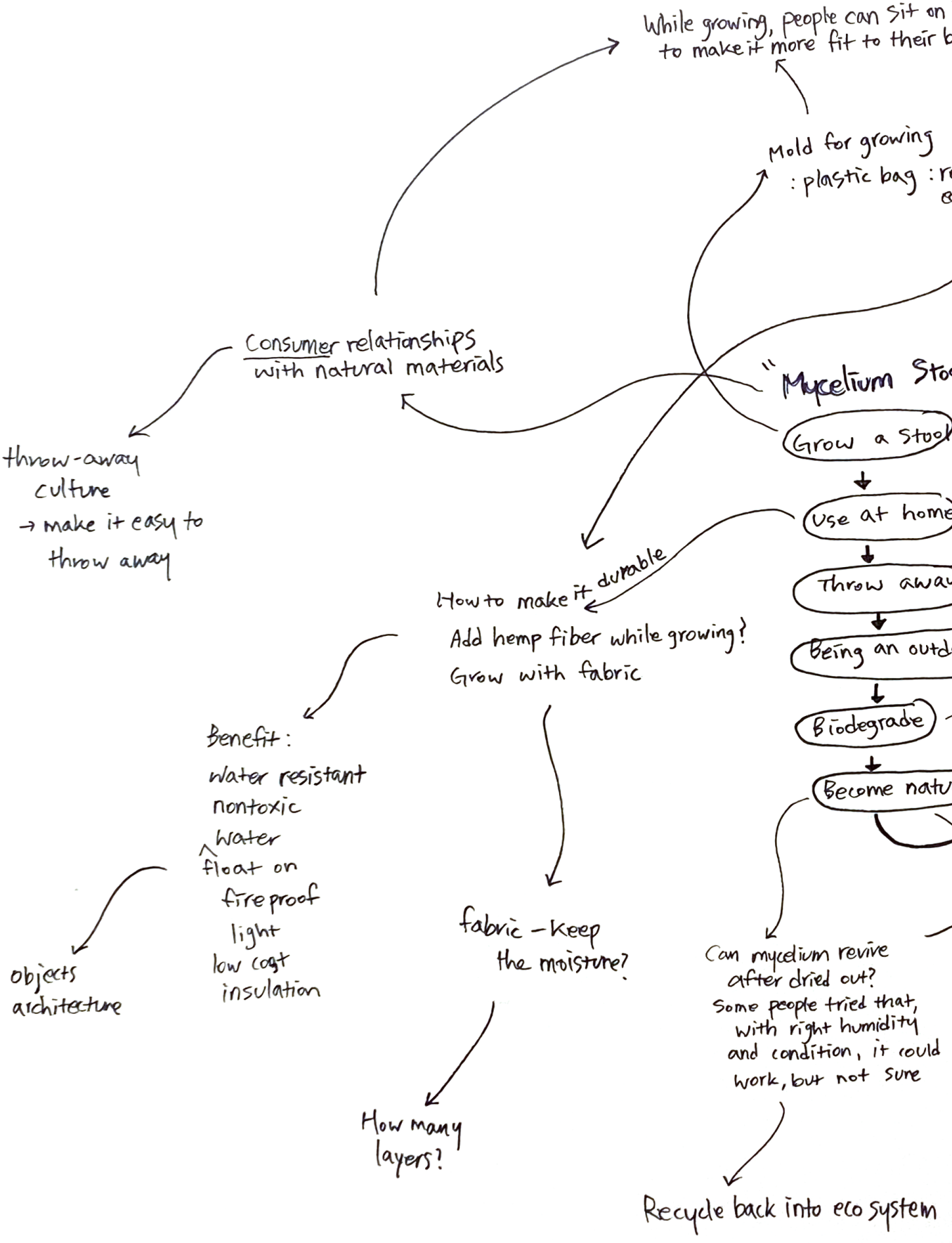
According to the EPA, Americans waste 12.2 million tons of furniture yearly, and 80.2% of it went to landfill. Only 0.3% of the f-waste(furniture-waste) that was sent to landfill was recovered for recycling. If we can't reduce f-waste , we can design furniture better for the world to begin with. Helping to treat the cause, not the symptoms.

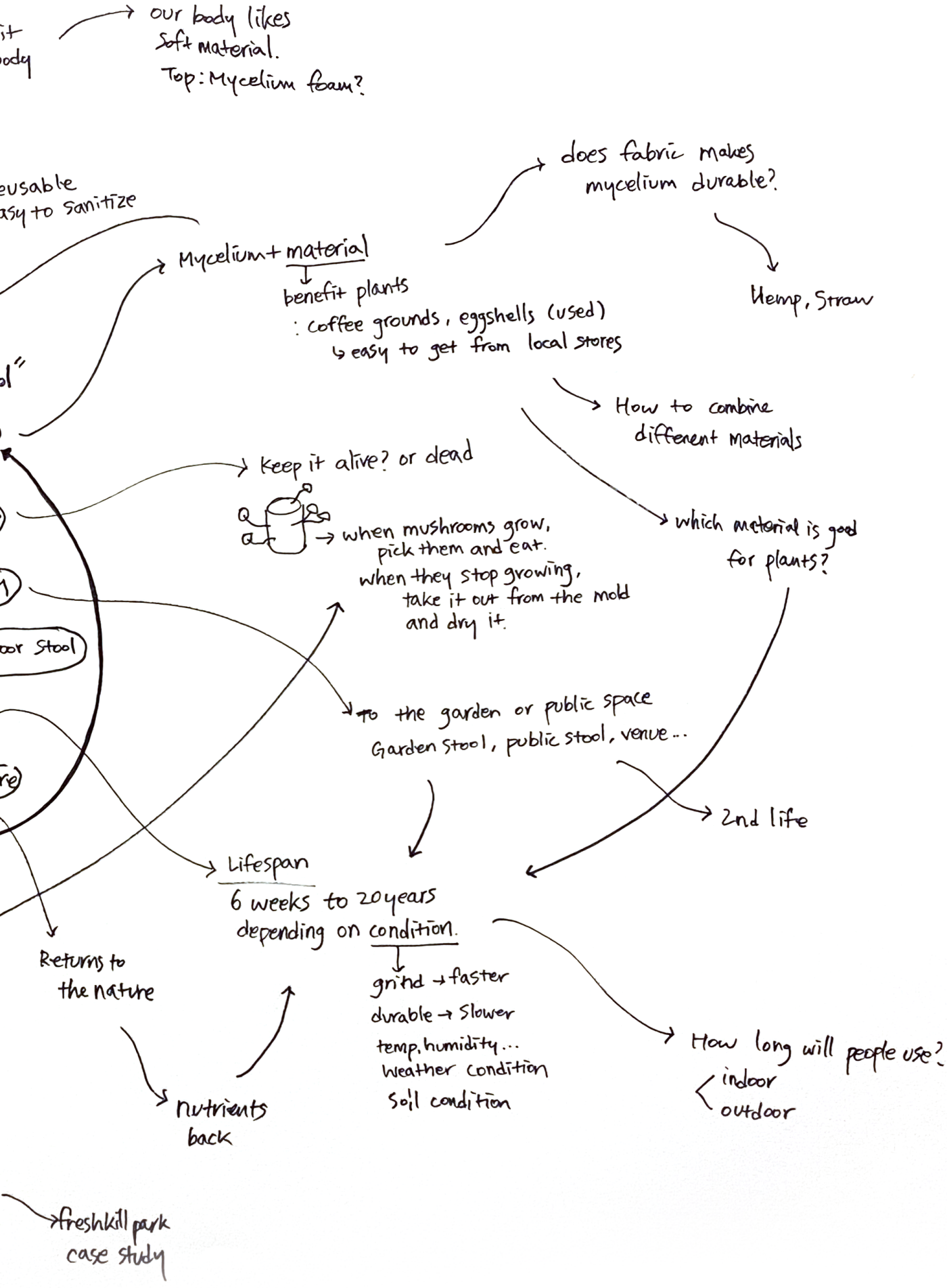
I decided to design a growing stool for the first project, which is a simple piece of furniture that people can use. By growing a stool out of mycelium, there are a lot of benefits that might build towards a more sustainable future. After using the stool for a couple of years at home, people can just let it decompose outside. This process can be defined as "Planting a stool outside" as well. The stools could have a role once outside as a public device for a while, then eventually they will biodegrade and be returned to nature.

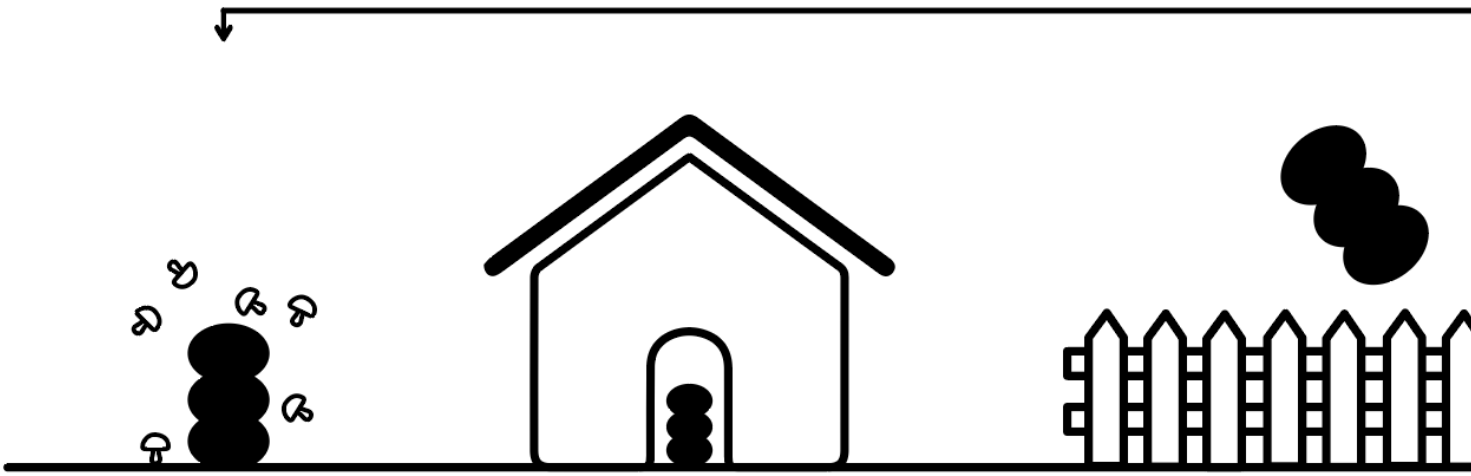
The stool uses used coffee grounds and eggshells from local shops like Knead Doughnuts and Rebelle Artisan Bagels. The stools will be grown in those composts, which are great nutrients for plants and trees in soil.

I collaborated on this stool with TJ Moon. My thesis is focusing on finding ways to use mycelium for manufacturing processes, while he is interested in valuing the knowledge and connecting between people. The aim was to find the making process accessible and feasible, and a means to engage communities in addressing waste issues for the positive effect.

Through this collaboration, I have learned how the mycelium stool manufacturing process should be done. It is not straightforward to control all the environmental conditions while fabricating. It is easier when it is manufactured in certain environments like factories or labs rather than purchasing the GIY(Grow It Yourself) kit and growing it at home, which means mycelium furniture is appropriate for mass production. From making this stool, I expanded my idea on how mycelium material could be applied to consumer electronics.


While growing, people can sit on
to make it more fit to their b
Mold for growing
: plastic bag : r
Consumer relationships
with natural materials
"Mycelium Sto
Grow a stool
Use at home
Throw awa
Being an outd
Biodegrade
Become natu
throw-away
culture
→ make it easy to
throw away
How to make it durable
Add hemp fiber while growing?
Grow with fabric
Benefit:
water resistant
nontoxic
water
float on
fireproof
light
low cost
insulation
objects
architecture
fabric - keep
the moisture?
How many
layers?
Can mycelium revive
after dried out?
Some people tried that,
with right humidity
and condition, it could
work, but not sure
Recycle back into eco system


our body likes soft material.
Top: Mycelium foam?
does fabric makes mycelium durable?
Hemp, Straw
eusable
asy to sanitize
Mycelium + material
benefit plants
: coffee grounds, eggshells (used)
↳ easy to get from local stores
How to combine different materials
keep it alive? or dead
when mushrooms grow, pick them and eat.
when they stop growing, take it out from the mold and dry it.
which material is good for plants?
oor Stool
to the garden or public space
Garden stool, public stool, venue...
2nd life
Lifespan
6 weeks to 20 years depending on condition.
grind → faster
durable → slower
temp, humidity...
weather condition
soil condition
How long will people use?
indoor
outdoor
Returns to the nature
nutrients back
freshkill park case study



MYCELIUM STOOL

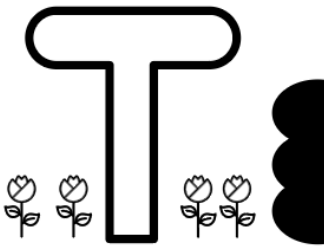
Mycelium stool will be delivered to consumers

USE AT HOME

Use the stool
People can grow edible mushrooms onto it as well.

PLANT IT IN SOIL

If you want to stop usi
you can plant it in soil

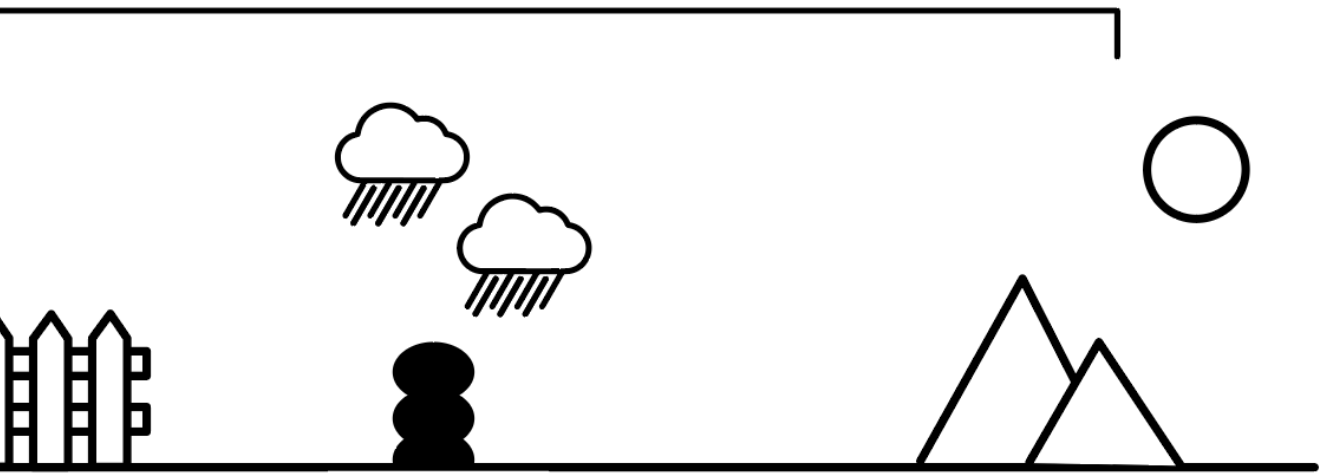


PLANT THE SEED

Our stool is made of
coffee grounds and mycelium.
It will helps plants to be healthy
if you plant seeds in there.

OUTDOOR STOOL

-Public stool
-Venue
-Garden stool



ng it,

→

BIODEGRADE

Lifespan:
6 weeks to 20 years
depending on the condition

→

RETURNS TO THE NATURE

Ready to be part of our environment

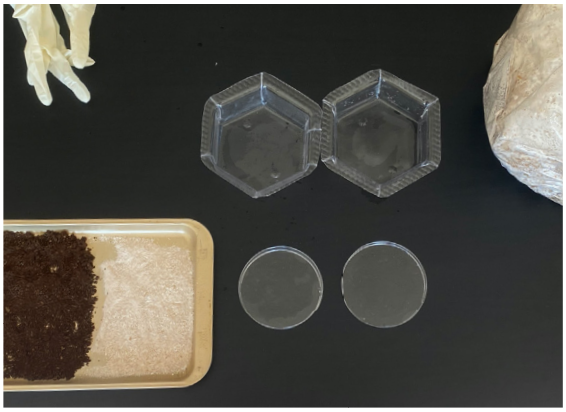
↓

L

CONTRIBUTE TO THE ENVIRONMENT

According to the EPA, furniture waste generated by Americans in 2017 totaled a staggering 12.2 million tons, and 80.2% of it went to landfill.
And, only 0.3% of the f-waste that was sent to landfill was recovered for recycling.
Fast furniture could be an environmental solution.

Before starting the project, we picked up used coffee grounds and eggshells every Thursday and Saturday from Rebelle Artisan Bagels and Knead Doughnuts for working on material experiments with mycelium.
This community engagement is a meaningful and important step for our design process.



Material experiments with mycelium (2/21/21)

Mycelium+Wood chips+Coffee grounds (3/2/21)

Material experiments with mycelium (2/21/21)

Mycelium+White millet (3/13/21)

Mycelium+Wood chips (12/8/20)

Mycelium+Ground eggshells (3/2/21)

Note

Mycelium grows well with substrates like coffee grounds/grains which have more nutrients. Ground eggshells did not work well since they are mainly calcium carbonate which is not a macronutrient for fungi.

First mold making practice with shower curtain (3/17/21)

First mold test - Growing mycelium with used coffee grounds and white millet (3/17/21)

First mold test - Growing mycelium with used coffee grounds and white millet (4/17/21)

Mycelium + Cheesecloth durability test (3/29/21)

A

B

C

Note

Through the experiment, I found A is a lot more fragile than B and C.
Cheesecloth did help a lot in terms of durability and keeping the moisture while mycelium is growing.

Mycelium + Hemp fiber durability test (3/30/21)

Note

Hemp fiber is also one of the great resources that I add in the mycelium growing process to make the structure stronger. It ties the overall structure together and is biodegradable.

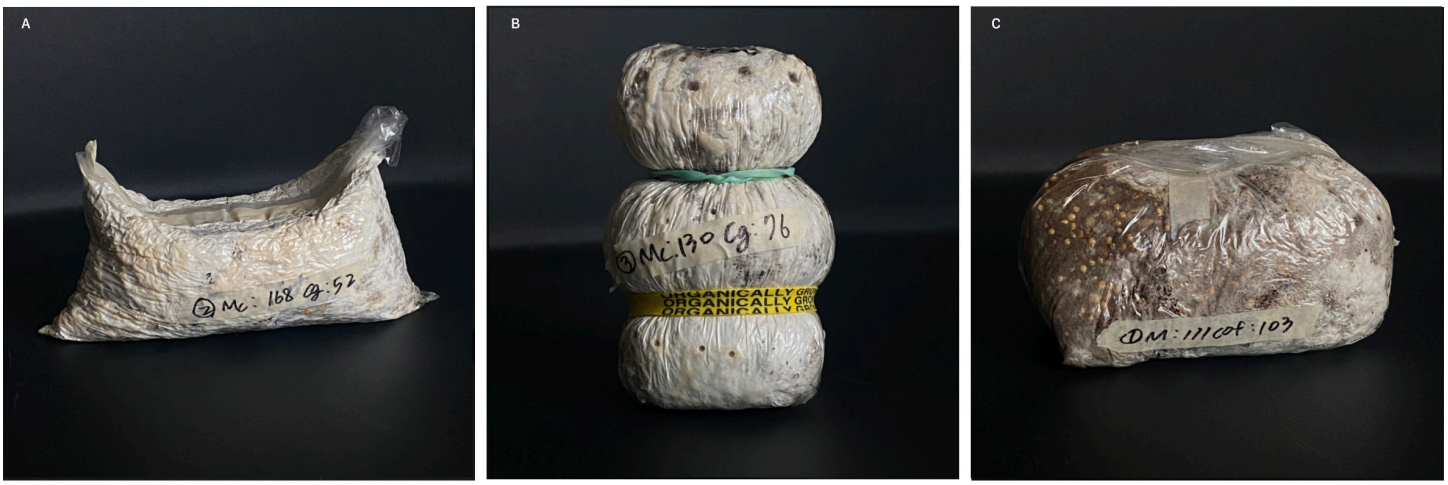
Activated mycelium : Coffee grounds racio test (3/29/21)

M:C = 168g : 52g
1 Layered fabric fully covered

M:C = 130g : 76g
2 Layered fabric covered on the bottom

M:C = 111g : 103g
2 Layered fabric 2/3 covered

Day 4 (3/23/21)

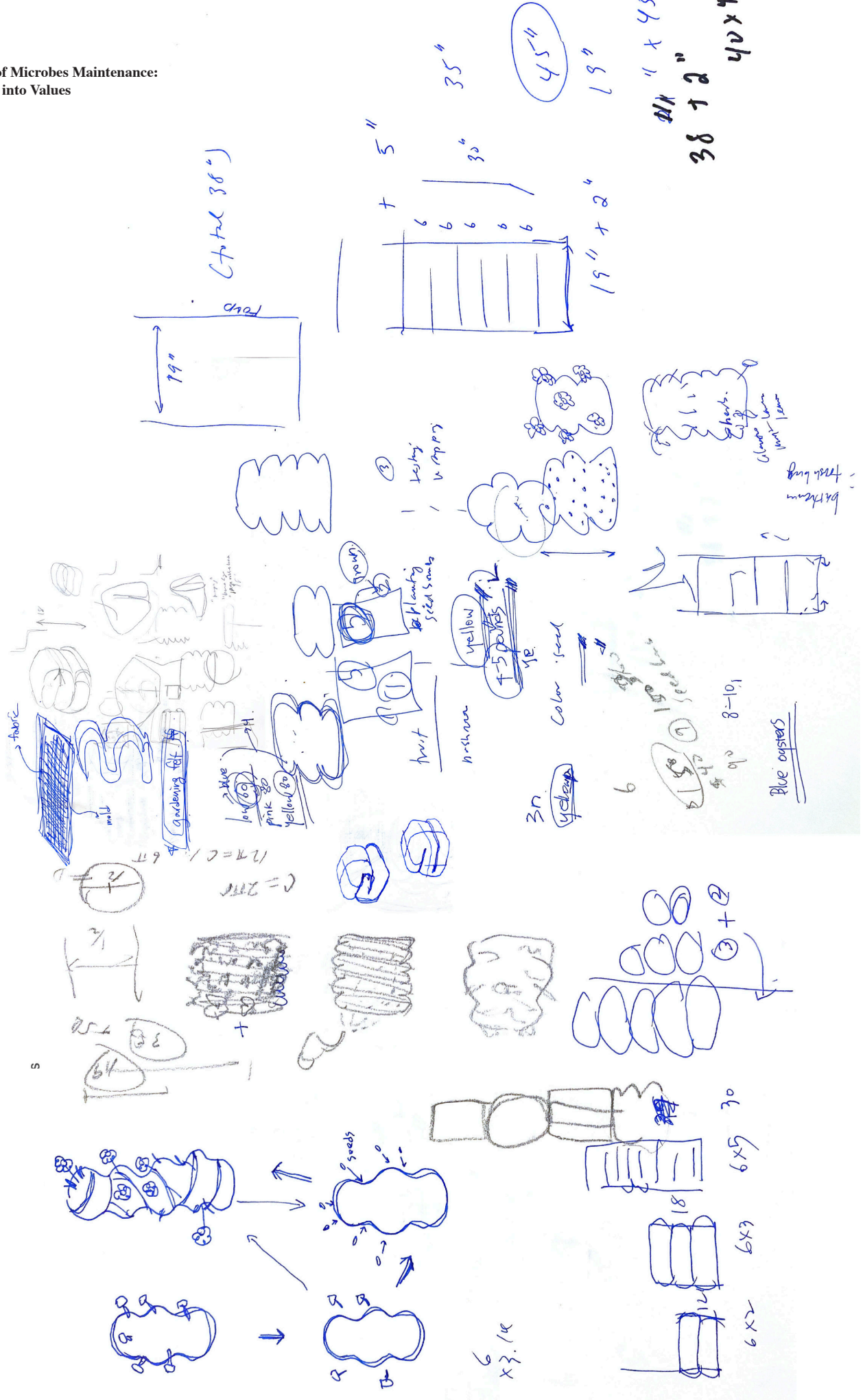


Day 10 (3/30/21)

Note

1. A and B grew very fast and C did not grow well. The ratio of mycelium/coffee grounds is very important.

2. Fabric plays a very important role in the mycelium growing process.
The fabric not only keeps the moisture, but also makes the material a lot more durable.


Fabric
gardening felt bag
mold
Blue oysters
seeds

Sprouts from mycelium (4/20/21)

Note

Mycelium has a lot of benefits when plants are growing with it. It will nourish their lives, help them absorb water, and build up the immunity of plants and trees.
I wanted to investigate if plants could be grown in mycelium stool as well. In that way, the stool can be the medium for sustaining their lives.

Final prototyping process

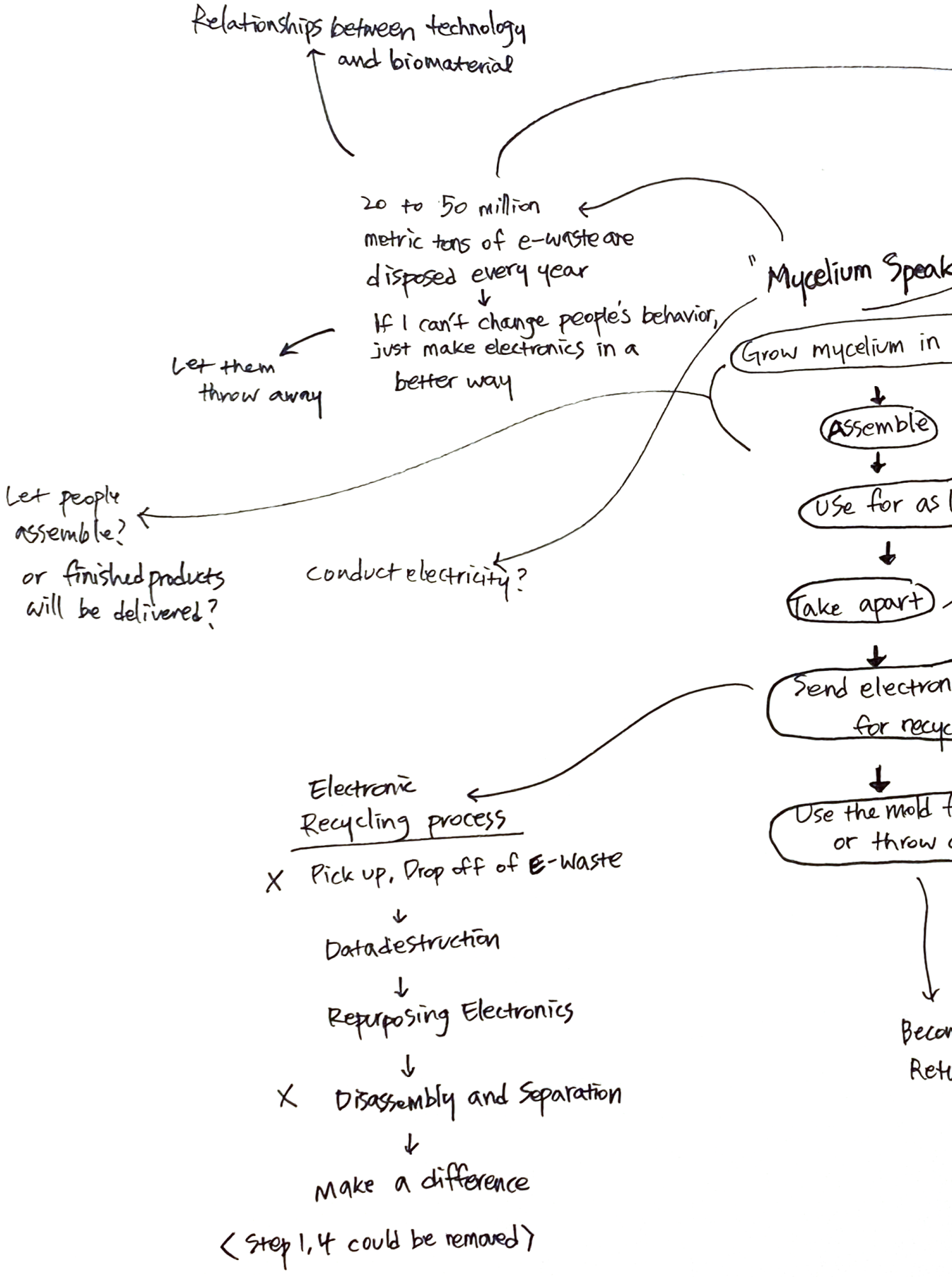
A fully grown stool (5/25/21)

A fully grown stool (5/26/21)

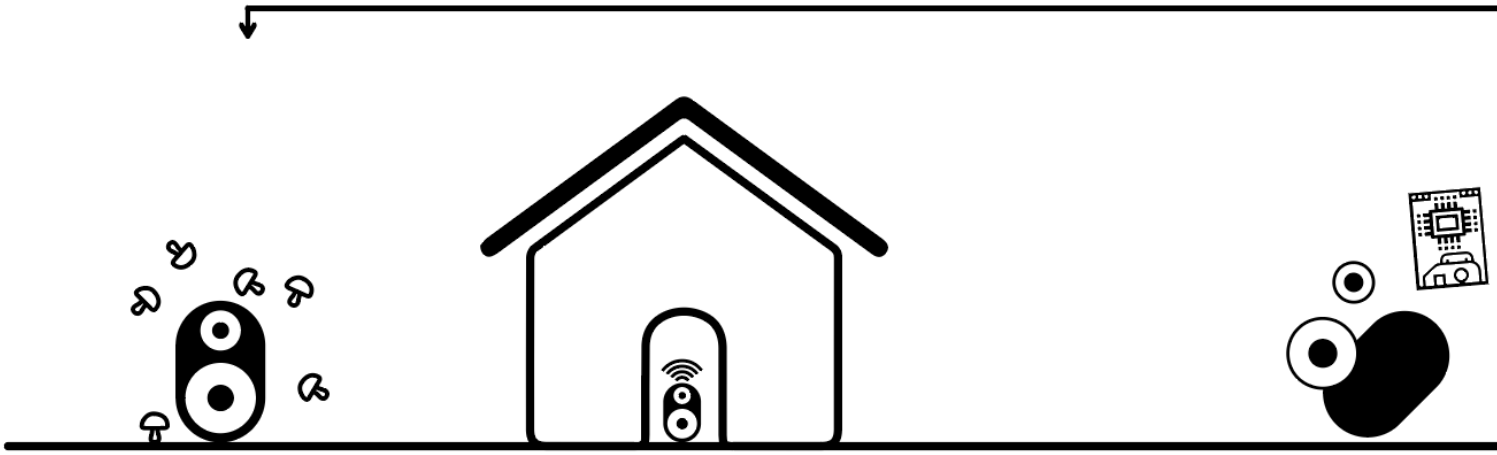
APPLICATION 2,
MYCELIUM SPEAKER

The world discards 53.6 million tons of e-waste(electronic-waste) every year, and only 17.4% was recycled, the United Nations reports. Americans generated 6.92 million tons of e-waste, about 46 pounds per person in 2019. It recycled only 15% of the material. We are throwing away billions of dollars worth of materials that could be used again. Even though many electronic device companies are making a lot of efforts on collecting recycled materials from customers, still the process is not easy. Through this project, I intended to find opportunities to address this e-waste problem. I aim to design this everyday simple object as a way to show that it is actually quite easy and accessible to make a change.

I am interested in how technology can be affected by biomaterials, and how biomaterials can influence technology. While researching, I found that sound can affect mycelium growth and mycelium could be a great material for sound insulation. By using 3D print technology and mycelium growing process, I would like to suggest a new way of producing casings for electronics which could contribute in a positive way to the environment.


Relationships between technology and biomaterial
20 to 50 million metric tons of e-waste are disposed every year
If I can't change people's behavior, just make electronics in a better way
Let them throw away
Let people assemble?
or finished products will be delivered?
conduct electricity?
" Mycelium Speak
Grow mycelium in
Assemble
Use for as
Take apart
Send electron
for recyc
Use the mold
or throw
Electronic Recycling process
X Pick up, Drop off of E-waste
Datadestruction
Repurposing Electronics
X Disassembly and Separation
Make a difference
(Step 1, 4 could be removed)


How to visualize the sound has changed because of mycelium?
manipulate the sound?
Relationships between mycelium/mushroom and Sound.
AI speakers
ex) Alexa's voice!
3D print
Filament : biodegradable
in soil : 6 months
regular room : up to 15 years
3D print mycelium?
Mycelium : 6 weeks to 20 years depending on the condition
3D printed mold
After using it as speaker, will I give it second life?
By making these processes easier, people can contribute for the environment
How to connect consumers with companies?
How to make people feel that they're contributing to the environment?



MYCELIUM SPEAKER → USE IT AS LONG AS YOU WANT → DISASSEMBLE

This process will contribu
to the environment.

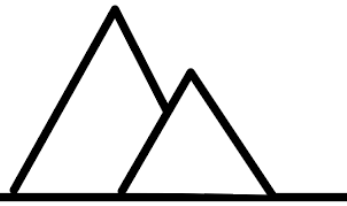
GROW MUSHROOMS WHILE LISTENING TO THE MUSIC

LET IT DRY AND KILL MYCELIUM

SEND COMPONENTS TO THE COMPANY

E-waste Recycling process

~~1. Pick up / Drop off E-waste~~
2. Datadestruction
3. Repurposing Electronics
~~4. Disassembly and separation~~
5. Make a difference



RETURNS TO THE NATURE

Ready to be part of our environment

LET THE CASING BIODEGRADE IN SOIL

Materials Lifespan

3D printing filament:
In soil: 6 months
Regular room: Up to 15 years

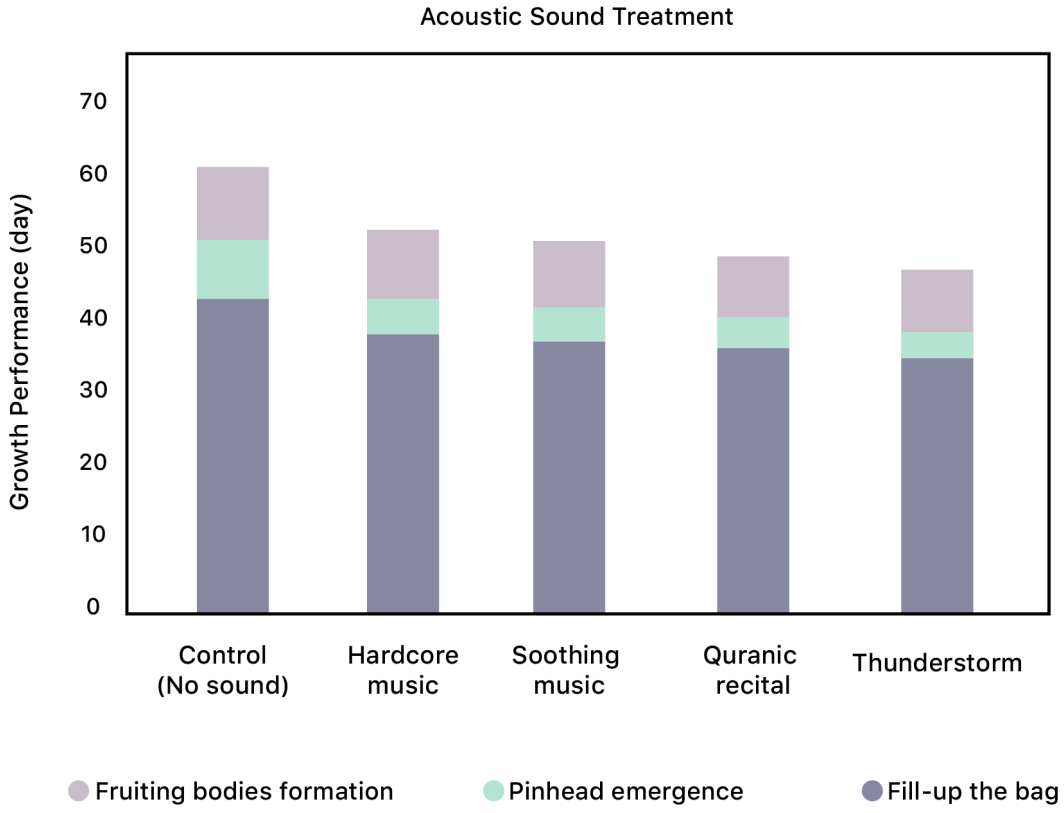
Mycelium:
6 weeks to 20 years depending on the condition

CONTRIBUTE TO THE ENVIRONMENT

The world discarded 53.6 million tons of e-waste in 2019. Only 17.4% of e-waste discarded in 2019 was recycled, the United Nations reports.

The United States generated 6.92 million tons of e-waste, about 46 pounds per person, in 2019. It recycled only 15% of the material.
We threw away billions of dollars worth of materials that could be used again.

If we can't change the Throw-away culture, making products in a better way is the solution.



The graph is based on the research document, *Enhancing Growth and Yield of Grey Oyster Mushroom (Plearotussajorcaju) Using Different Acoustic Sound Treatments.2016*.

Note

Mycelium is good for sound insulation, which means if it is used as a speaker casing, it prevents the sound from directly hitting the wall. I wanted to experiment to see if mycelium speakers can enhance the sound quality.
Through further research, I found that mushroom growth is expedited when louder sounds are played. It was an interesting starting point for making a mycelium speaker. This discovery inspired me to use the specificity of the material to make an everyday object which interacts with sound, such as a speaker.

Dried mycelium block sound delivery test (3/10/21)

Figure 8.3 A piezo driver and contact mike pickup being used to filter a sound through a sheet of plastic.

You can create feedback by plugging a contact mike into the amp input and a piezo driver into the output, and attaching the two to the same object. Flexing or dampening the object can affect the feedback pitch, and turn a piece of garbage (such as the much-despised molded clear plastic packaging from toys) into a playable instrument—an electronic musical saw. You can configure several channels of amps, drivers, and contact mikes to send audio signals through a series of objects for multi-stage processing; using Y-cords you can branch off and mix after each resonator-object. Get together with your buddies, find a small garage, and form a piezo band. (See Chapter 26 for more information on matrix processing.)

Whereas size does not greatly affect the loudness of a contact mike made from a piezo disk, it makes a big difference when you are making a driver. If you have a choice, use the largest possible disk and you get a bigger sound out of whatever you are driving. You will notice that this is not a "high fidelity" device: the sound is often limited to high frequencies, displays the peaked resonance inherent to a piezo disk, and can be quite distorted—larger disks have a wider frequency response, as well as being louder and less distorted than small ones. You can insert some equalization, in the form of an inexpensive "stomp box" graphic EQ, to process the signal driving the piezo disk and/or the contact mike picking up the vibrating object. Substituting a more powerful amplifier, such as a boom box with external speaker jacks, for the Radio Shack mini test amplifier, will also give you more volume before distortion. The benefits of equalizers and stronger amplifiers will be especially noticeable when you set up the matrices and feedback systems

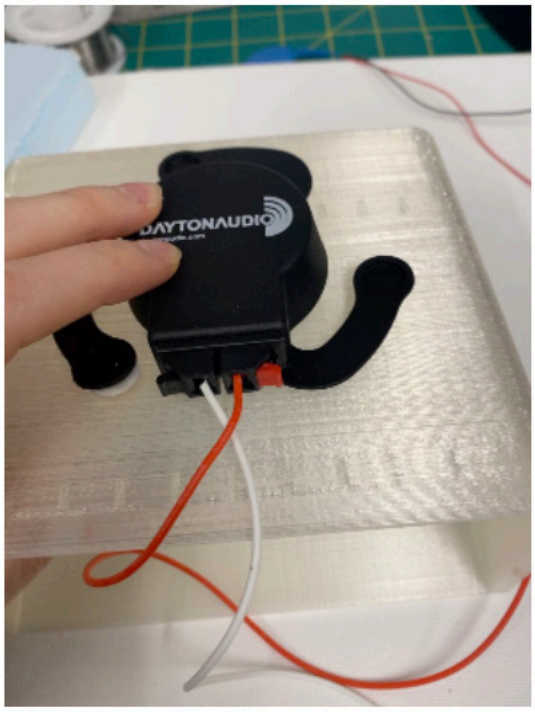
You can also make a pretty efficient driver by gluing a cork to the center of a small loudspeaker (see Figure 8.5). Connect any sound source through an amplifier to the corked speaker and hold the speaker against a sheet of metal, drumhead, cymbal, etc. The cork should vibrate the material and process the original signal. You may want to pick up the vibrating surface with a contact mike. The end of cork can be treated to further affect the sound: a thumbtack brightens it (like a honky-tonk piano), while a piece of felt softens it, and wood is somewhere in between.

A nice, simple spring reverb can be constructed by stretching a fat spring or Slinky between the center of a speaker cone and a contact mike. You can attach the Slinky to the cone with tape, glue, or a sandwich of self-adhesive Velcro.

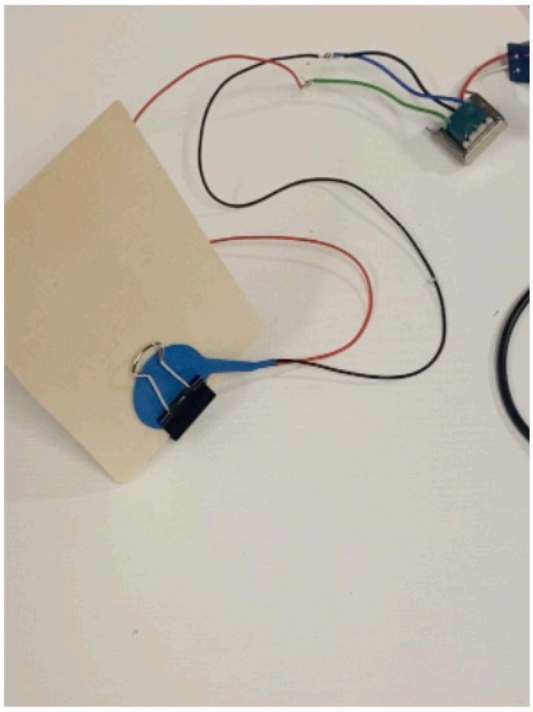
There are commercially available transducers as well. Richtech Enterprises still manufactures the "Rolen-Star" wide-range driver originally used by Tudor for "Rainforest" (see Figure 8.6). Several companies make low-frequency drivers—essentially subwoofer transducers—for use in car sound systems, home cinemas, and to increase the realism in computer games. Aurasound's "Bass Shaker" bolts to the floor of your trunk and turns the whole back end of your car into a big subwoofer (see Figure 8.6). Similar drivers include the SmartDisk Tactile Sound Transducers, the Sonic Immersion I-Beam, and the delightfully named "ButtKicker." All of these require 10–30 watts of power, however, and cannot be driven from a mini test amp or boom box.

For more modest sound pressure levels, the "Soundbug" from FeOnic consists of a battery-powered amplifier and transducer package with a suction cup for affixing it to most smooth surfaces; it can be driven directly from the headphone output of a computer, portable CD player, MP3 player, etc. The SI-5 portable speakers by Sonic

Figure 8.5 A corked speaker.



3D printed object



Wood

Blue foam

Mycelium foam

Material sound delivery test (3/21/21)
Link: https://docs.google.com/presentation/d/1hJpCsK1TJEs6QfKsOSx68U_3NlETuN6NX66prOlG9ig/edit?usp=sharing

Piezo disc on blue oyester mycelium
(LM386 Amplifier connected)

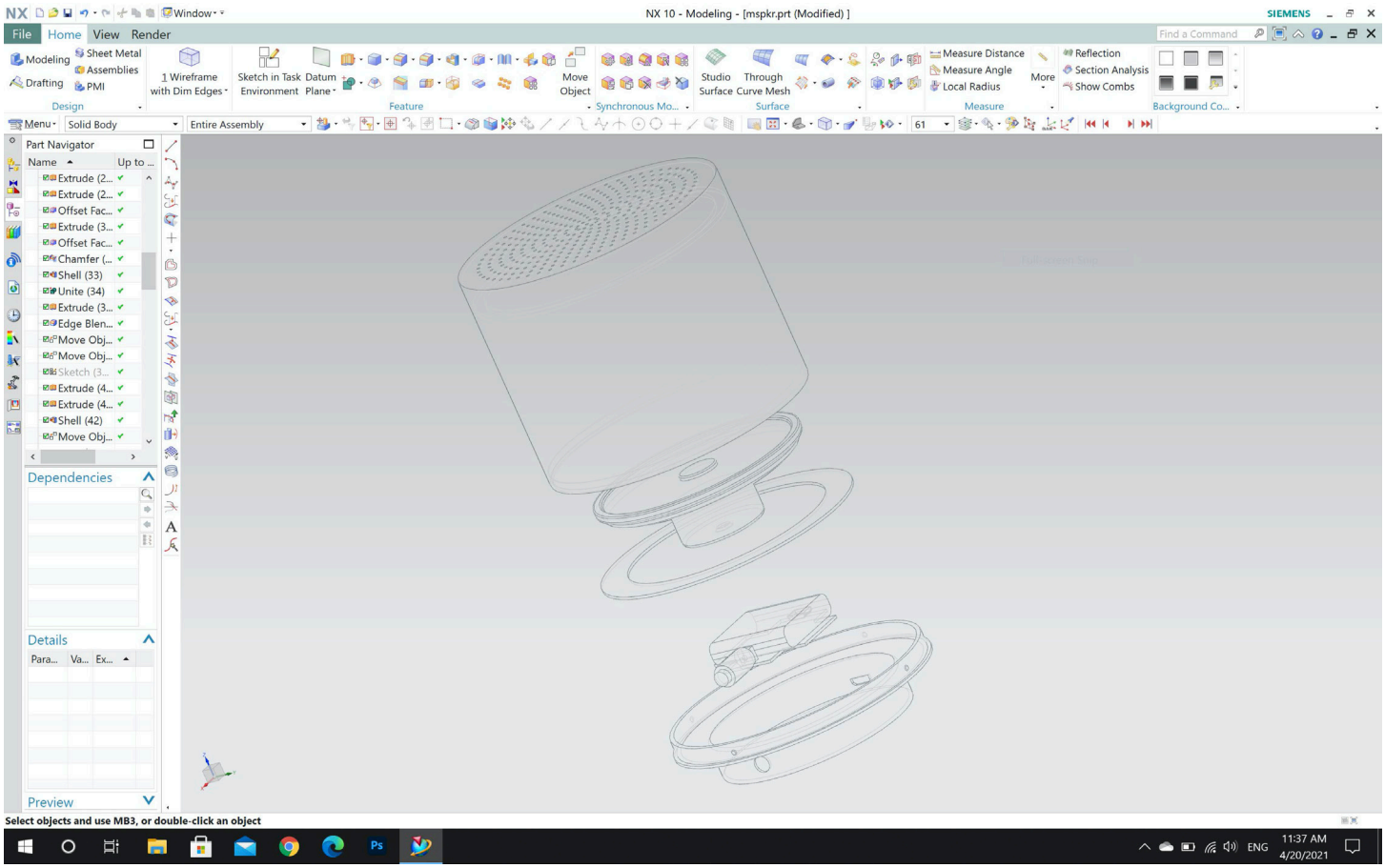
Piezo disc, Contact mic on blue oyester mycelium
(LM386 Amplifier connected)

Dayton Audio Sound exciter on blue oyester mycelium
(LM386 Amplifier connected)

Mycelium sound filtering test (3/21/21)

Note

After reading a book, "The art of Hardware Hacking" by Nicolas Collins, I was wondering how different materials deliver the different sounds.
Through the sound delivery and filtering test, I realized that mycelium absorbs the sound and vibration very well compared to other materials.


NX 10 - Modeling - [mspkr.prt (Modified)]
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Modeling Sheet Metal
Drafting Assemblies PMI
Wireframe with Dim Edges
Sketch in Task Environment
Datum Plane
Move Object
Studio Surface
Through Curve Mesh
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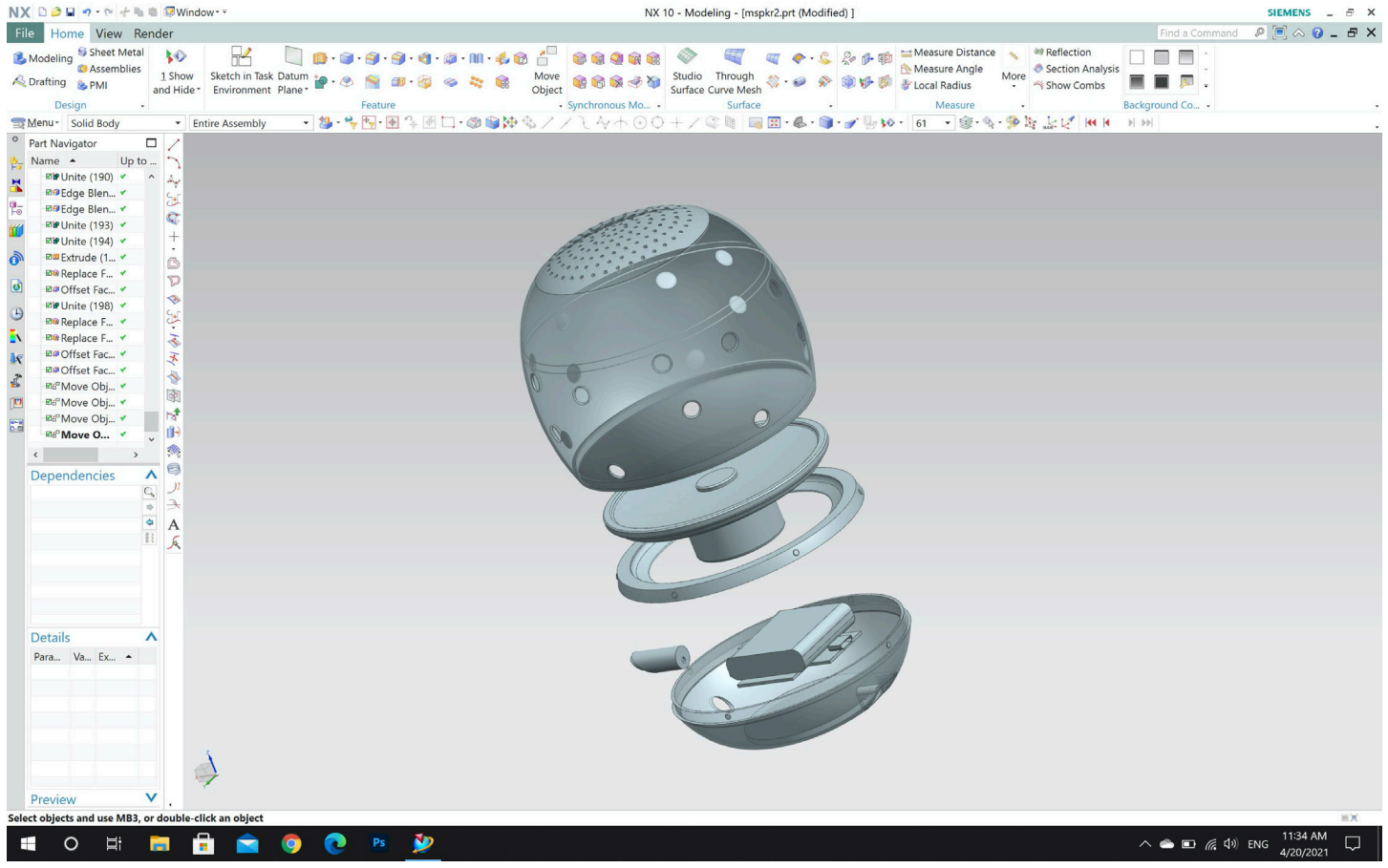
NX 10 - Modeling - [mspkr2.prt (Modified)]
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File Home View Render
Modeling Sheet Metal
Drafting Assemblies PMI
Show and Hide
Sketch in Task Environment
Datum Plane
Move Object
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Through Curve Mesh
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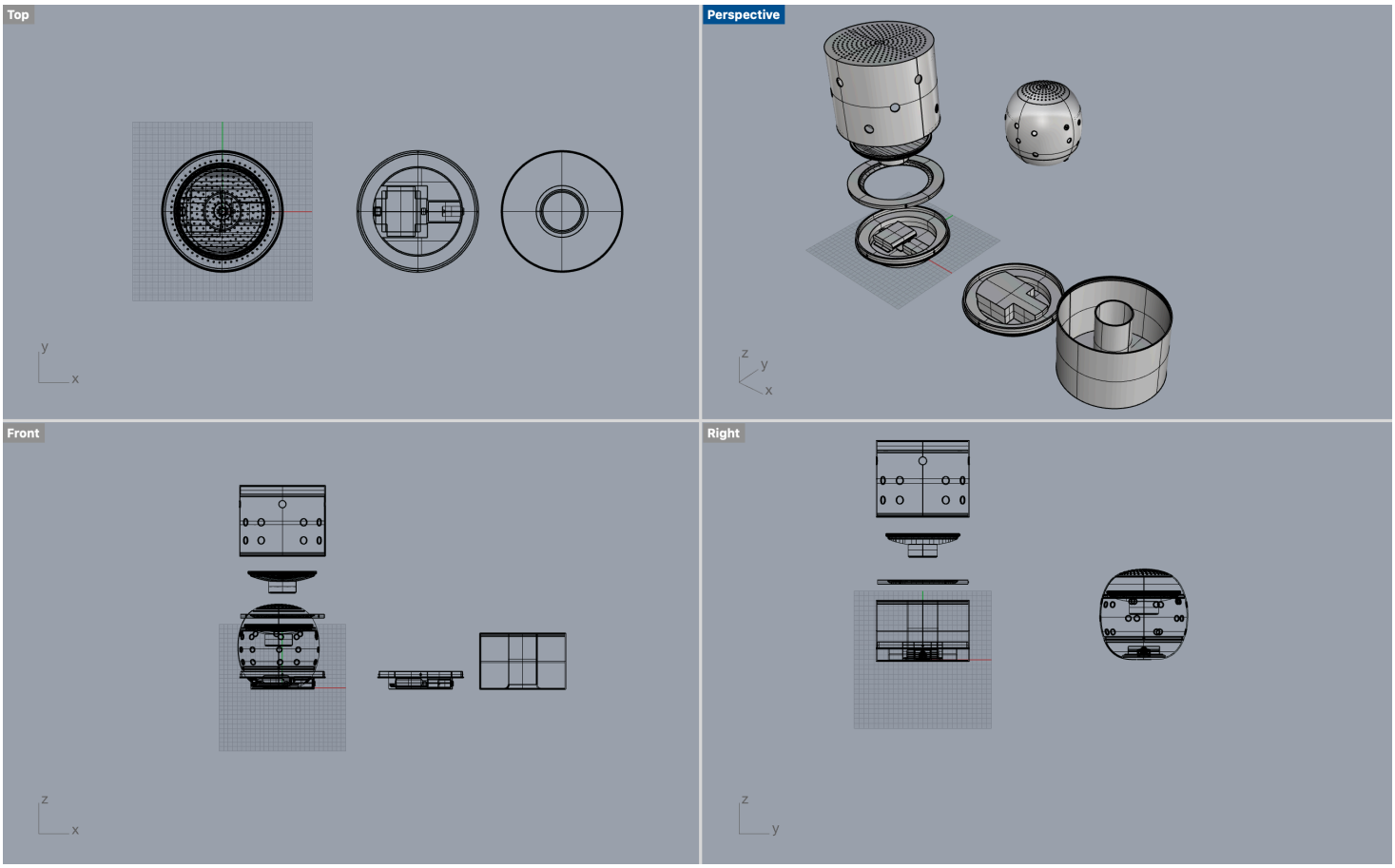
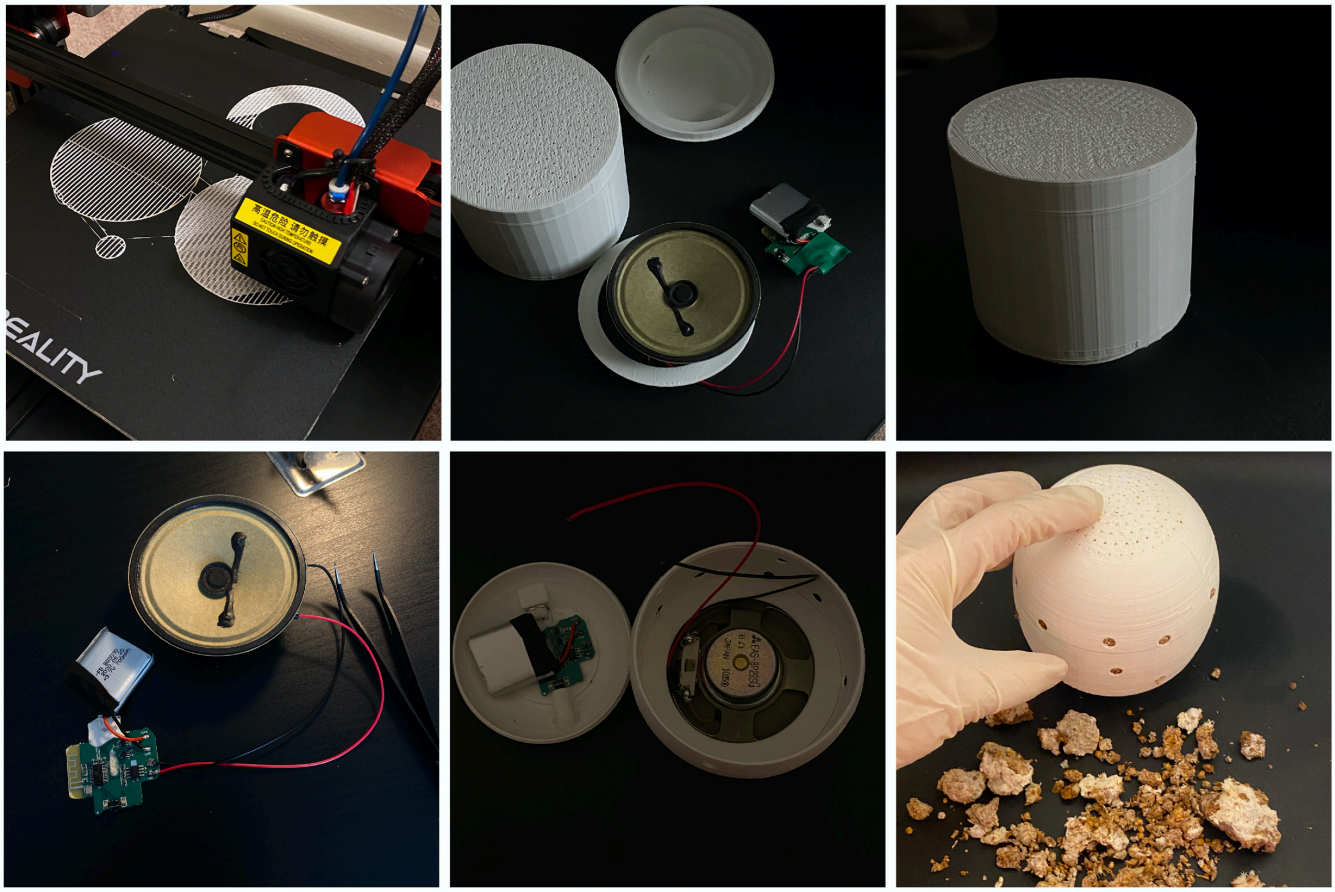
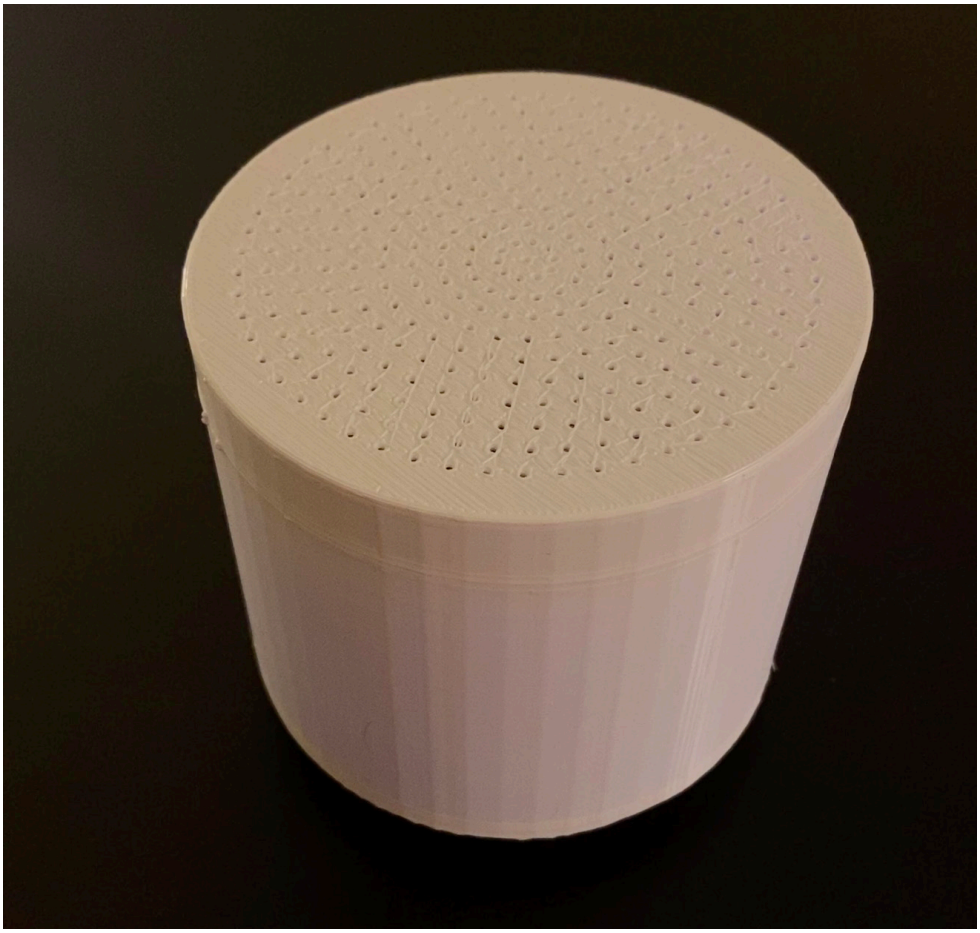


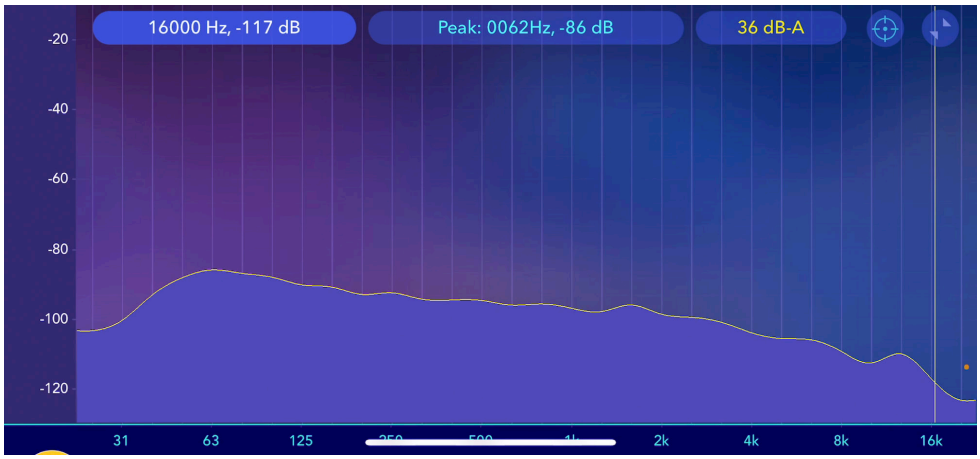
Note

I modeled 3 prototypes to put the electronics in to test the speaker.
By working on assembly structures and revising them, I tested sound quality.



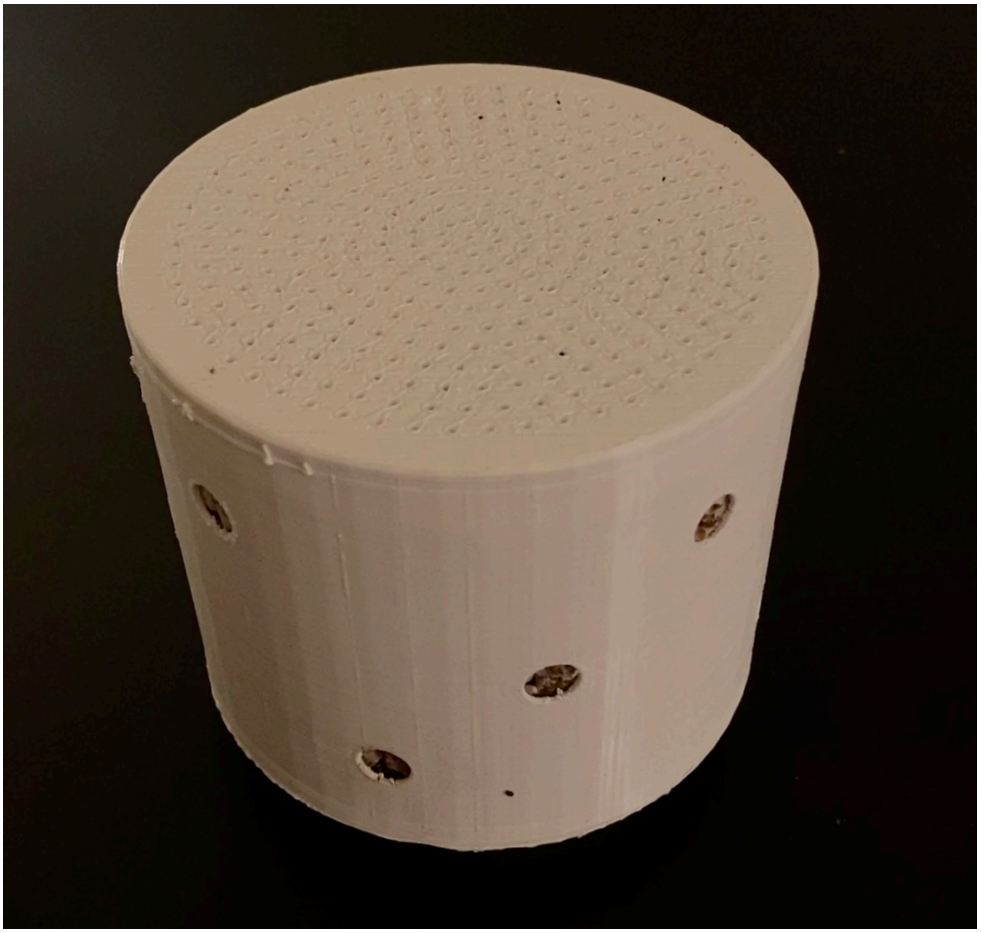
Prototype tests

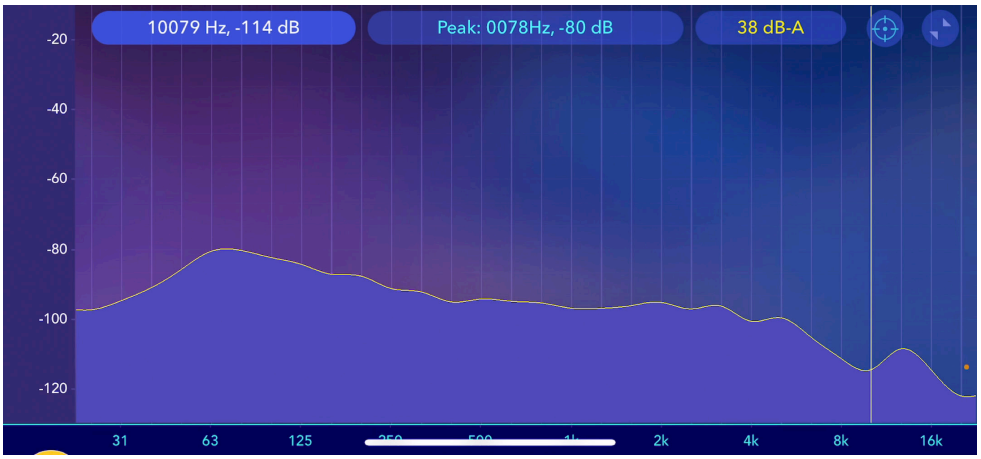




Note

The 3D printed speaker creates some breaking sound and vibrates a lot during playing the music, since the sound directly hits the 3D printed wall.





Note

The 3D printed speaker filled with mycelium makes sounds softer.

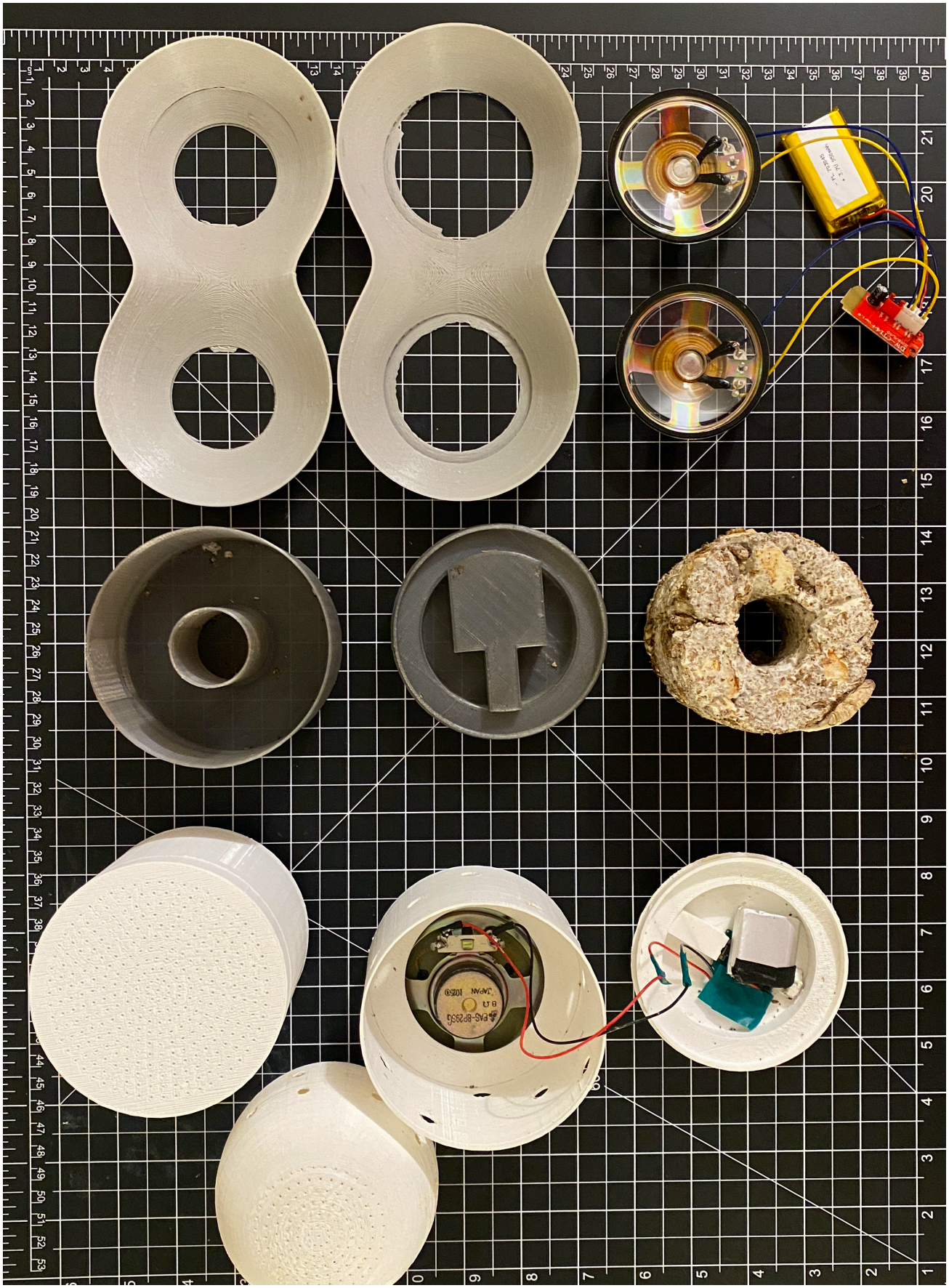
Link: https://docs.google.com/presentation/d/1h8RAQfwWHfe8jxakONDfulg6gNfKEmU1cS3bq_AI5HM/edit?usp=sharing

Note

I made holes for growing mushrooms from the inside mycelium casing. Since the holes were so small that they couldn't grow nicely, it was still interesting to see how mushrooms are growing while we are listening to music. When the hole size is bigger, the more mushrooms will grow.

Note

Since the hole size was small, mushrooms were squeezed inside as well.



Final prototyping process

Mycelium Speaker 1

Mycelium Speaker 2
Link: https://drive.google.com/file/d/125VQdMpUDHC51dhiGHLTyQV2akcXUj97/view?usp=sharing

ANNOTATED BIBLIOGRAPHY

Michael, Pawlyn. *Biomimicry in Architecture*. RIBA Publishing. 2016.
Pawlyn explains how architects can build a new world of sustainable beauty by learning from nature. To think about how the output of the design can affect human wellbeing in the future is also a crucial subject that I need to carefully consider.
I know how important it is to find the right elements and put them together in a sustainable way. Especially in terms of manufacturing, using all toxic elements in the periodic table is adversely affecting nature. Designers have to be responsible for what we design. I will always explore ways to integrate design with natural systems to make it meaningful.

**Jelte, van, Abbema. *Symbiosis*. Dutch Design Week. 2009.
https://www.dezeen.com/2009/10/27/symbiosis-by-jelte-van-abbema/**
This printed letters with bacteria project shows possibilities of living organisms in visual culture. The work that I've done last year was coloring materials with bacteria. One of my experiments was printing coasters with bacteria. I grew patterns with bacteria, transferred them onto the wood coasters and killed them. In that experiment, like Jelte did, I wanted to show people that bacteria themselves can create patterns and we can use them when we produce things. I believe that bacteria can give us a lot of opportunities for design, and I would like to explore them more.

Neri, Oxman. *Imaginary Beings: Mythologies of the Not Yet*, Paris, France, 2012. http://materialecology.blogspot.com/2012/05/imaginary-beings-centre-pompidou.html
The project, *Mythologies of the Not Yet* shows 18 prototypes which explain human bodies. Each of these series of design explorations are inspired by human functions.
Her idea of the design employs augmentation of human power and the built environment. It is impressive to think about how living organisms can be a model for design and fabrication. Also this project made me consider that humans can expand our power by using biotechnology.

Neil, Harbisson. *I listen to color*. 2012.
https://www.youtube.com/watch?v=ygRNoieAnzI
Neil is a color-blind person. So, he made an antenna to distinguish different colors and implanted it to his skull. Instead of seeing colors, he is listening to them, and he considers the antenna as one of his organs. After watching his TED lecture, the most interesting thing for me was how technology can connect humans to the world. Thanks to technology, he now listens to different pictures and environments, even he can distinguish ultraviolet color, which other people cannot see. Using technology in design for humans in the right way is what I'm trying to do these days.

Hara Kenya. デザインのデザイン*(Designing Design)*. Iwanami Publishing. 2003. Tokyo, Japan.
In terms of designing long lasting products for people, Hara Kenya is one of the best desig ners who pursues that. I think there is a lot of meaning behind sustainable design. Generally, we think it means making things with sustainable materials or recycling resources. But I believe that timeless design could also be the green design. If people want to keep it for their lifetime and fix it because they do not want to lose it, that is the best design and we can say it is sustainable.

Rushabh, Haria. *Is 3D printed bacteria the future of electronics?*. 2018.https://3dprintingindustry.com/news/3d-printed-bacteria-future-electronics-128454/
Micro-organisms also can create structures and be 3D printed. Because they are alive, it is a good way to interact with people. This new way of thinking about micro-organisms themselves as objects is innovative. David Benjamin, an architect is also known for suggesting building structures made with cells. 3D printing with micro-organisms has a lot of potential. In the future, I can imagine the objects made with microbes fix themselves when they need to be, and get bigger or smaller by themselves.

NASA's Ames Research Center. *How Bacteria That Make Electricity Could Help Us Colonize Mars*. 2018. https://www.youtube.com/watch?v=KhsCg7pmv0o&feature=emb_title

I'm also interested in generating energy with microbes. The project, Wanderers by Neri Oxman is also based on the idea of using bacteria as electrical energy resources in space. Maybe later, microbes will be able to swim inside narrow wires connected to electronic products to supply electricity to our devices. We will keep feeding them or taking care of them to get power supplies, and growing them carefully can be an important task for humans in the future.

Edward, Steichen. *Edward Steichen's Delphiniums*. MoMA. 1936. https://www.moma.org/explore/inside_out/2011/03/08/edward-steichen-archive-delphiniums-blue-and-white-and-pink-too/

This is the first bio art project exhibited in MoMA. The photographer Edward showed his delphiniums which he has grown for 26 years.
He marked the beginning of exhibiting living organisms. This work is meaningful as it narrowed down the relationship between art and living, by showing people that this kind of work can be considered as one of the categories in art. After this work, a lot of bio art projects came out.

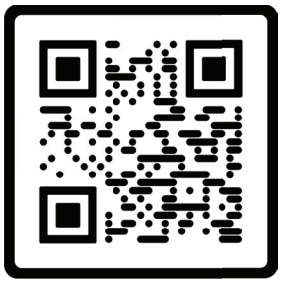
Neri, Oxman. *Wanderers, An Astrobiological Exploration*. Euromold, Frankfurt, Germany, 2014. https://mediatedmattergroup.com/wanderers

Wanderers are Inspired by nature, the 3D printed wearable capillaries, that are designed for containing microorganisms. They interact with specific environments and generate bio-energies that we need for living. The idea that living organisms around us can be used as natural resources in the future made me think about ways to connect nature with industrial design for both environments and humans.
When we design things, we are trying to find the solutions from human made technology. But, when we look into the natural world carefully,

there is a mass of material that we can fully use. Instead of paying attention to technology which can harm us and our surroundings, we need to interact with nature and materialize the ways to communicate through design.

Oron, Catts and Ionat, Zurr. *Victimless leather*. 2004. https://tcaproject.net/portfolio/victimless-leather/
Sometimes, animals are victims for humans. We are using them by wearing leather or fur, eating steaks. This project lets people rethink those ethical issues. The leather jacket shape is made of cells and when the cells are getting fed, the jacket gets bigger, and to keep the size, people need to stop feeding the cells. This bio art helped me to see things widely, in terms of expanding life rights and defining new standards. Reminding us that all creatures' lives are equal, and understanding their essentials are what we need to do for a sustainable world.

Roshita Ibrahim, Ahmad Azmil Irfan Mohd Jamil, Sayed M. Zain Hasan, Adzemi Mat Arshad, and Zarina Zakaria. *Enhancing Growth and Yield of Grey Oyster Mushroom (Plearotussajorcaju) Using Different Acoustic Sound Treatments*. 2016. https://www.matec-conferences.org/articles/matecconf/pdf/2017/11/matecconf_etic2017_01054.pdf/
This research paper inspired me to work on the mycelium speaker. How mushrooms are affected by music was an interesting starting point for me. The relationships between electronics and nature sounded fun to investigate.



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May, 2021

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