MYCONNECTION

the endeavour of bonds with nature

mycelium material study

Malina Tezycka | Material Turn | Chalmers University of Technology

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Malina Tezycka

Master Thesis in Architecture and Planning Beyond Sustainability
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Examiner: Kengo Skorick
Supervisor: Jonas Lundberg, Jonas Runberger

abstract

The development of agriculture allowed the human population to grow many times larger than thousands of years ago. Nearly all agricultural practices generate waste in large quantities in numerous countries, while the great advantage of its reuse is omitted. Diverse agricultural, cellulose-based waste substrates are being burnt causing a major source of environmental pollution in developing countries. Incorporating the biomimicry’s ideology, where one organism’s waste material becomes another’s raw material, in the building industry partly brings relief to the environment. Moreover, the meeting point of science and design would allow biology to produce building materials.

This thesis explores the potential of bio fabrication and the reuse of biowaste as a paradigm shift toward providing a circular economy by designing materials that can be reused, repaired, and remanufactured. The main scope of the research focuses on the compound of agricultural solid-waste substrates and mycelium. Research has shown that mycelium performed the ability to create a self-grown vast network, binding parts of organic substrate allowing us to produce bio-composites for various uses.

The thesis involves biologically driven research to explore the qualities delivered by the composites and their application in the design of an outdoor teaching pavilion, as a tool for human and nature coexistence. The circumstances that we experience in the early stages of our life have a great impact on the shape of our personalities. The concept of outdoor learning concentrates on education through practical activities providing long-lasting effects of the skills development essential for modern life, such as communication, innovation, team spirit, autonomy, and creativity. The greatest values that drive the concept of biophilia are impossible to perceive with the bare eye. The project will attempt to discover such conditions through material-driven design.

Keywords: bio-fabrication, mycelium, outdoor school, material design

table of content

"The world is full of wonderful things you haven't seen yet. Don't ever give up on the chance of seeing them."

J. K. Rowling

thank you

Jonas Lundberg, Jonas Runberger, Kengo Skorick

Vijayendran Raghavendran, Carl Johan Franzén

Birgitta Rorsman, scholarship committees of Britt-Lisa Landahls Fond

Gothenburgs Preschool

Adam

Friends & Family

student background

education

master program: Architecture and Planning Beyond Sustainability
Chalmers University of Technology

bachelor of architecture
Gdansk University of Technology

profession

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thesis questions

How can biofabrication change the ways that we design our environment?

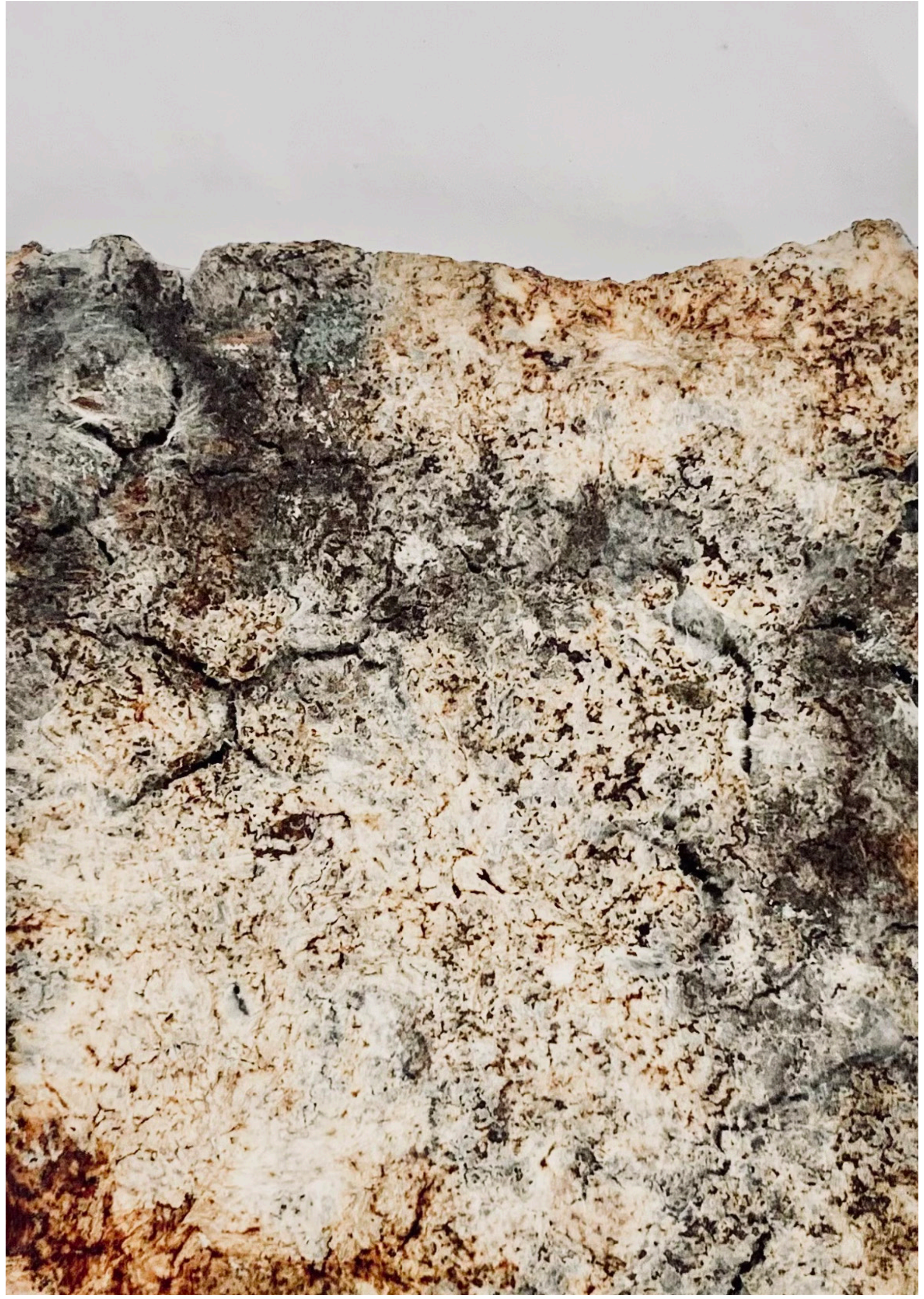
How can human-nature relations be built through the the use of bio-agricultural waste in outdoor teaching spaces?

What qualities can the application of mycelium bring to building environment?

Aim
This thesis proposes the design of a pavilion in which mycelium plays the main role as a building material that enables a direct connection between humans and nature, and meet the needs of a forest school. It is intended to explore the qualities brought by the mycelium composites in architectural and educational way, through series of practical experiments. The study investigates the process of creating self grown materials from stratch - from fungi to mycelium composite. The pavilion structure is designed to provide a sheltered space while applying materials that come direcly from natural environment and can be biodegraded, reused or remanufactured or redesigned. The design application structure is used as to demonstrate the research findings, while the actual design can be adapted to different environments and scales.

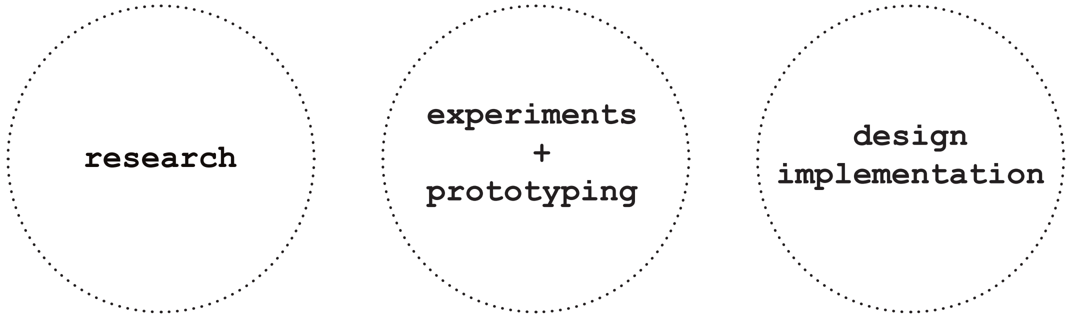
Delimitations
This thesis does not focus on testing different strains of mushrooms, but one to see how various substrates influence the proferties of the composites.

Does not aim to create new myco-material.



methodology

Methodology practiced in this thesis incorporate the following phases:



The process of this thesis began with the research followed by a series of experiments, in which the main goal was to learn how to grow mycelium material from scratch. The growth of mycelium cultures on agar and among various substrate materials was explored to test their functional, physical and esthetical values. The design implementation came to be naturally the extension of the process, becoming a reflection of the research and demonstration of experiments findings. The research phase consisted of literature studies and 2 days site visit at the Gothenburgs preschool.

The prototyping phase correlated very much with the design implementation, as those two were very dependent on each other, due to explored potential of the material. During the design phase, the implementation of mycelium composites was studied in terms of creating flexible spaces for outdoor schooling, suitable primarily for kids.

All the places influenced each other as the whole process was very explorative and not fully under control as it was driven by self-grown material - mycelium.

"Biodesign is to work in this very intimate encounter. You provide the conditions for the organism to grow in a certain way, but the organism will do its own thing. Sometimes you believe you are manipulating it, but the organism is manipulating you in its way too. It's kind of an awkward dance."

Correa

BACKGROUND

"Earth and sky, woods and fields, lakes and rivers, the mountain and the sea, are excellent schoolmasters, and teach of us more than we can ever learn from books."

John Lubbock

introduction

As the 21st century became a century of biology (Venter and Cohen, 2004), the shift toward the use of biofabrication and biomaterials became noticeable; however, fundamental changes within the building industry are yet to come. Biomimicry provides a whole range of solutions that benefited from a 3.8 billion year research that nature did to master the creation of the most functional and efficient systems and materials.

Biology has already mastered ways to handle waste that we humans generate, contributing to climate change, air pollution and harm to other ecosystems and species. Known by humans concept of waste products and other related problems does not exist in nature, where resources are maintained in the closed-loop cycles. (Pawlyn, 2016)

biophilic design

"The concept of biophilia implies that humans hold a biological need for connection with nature on physical, mental, and social levels and this connection affects our personal wellbeing, productivity, and societal relationships."
Sheep's Meadow, 2004

The concept of biophilic design is strongly associated with a love for living. The greatest values that drive the concept of biophilia are impossible to perceive with the bare eye. Many studies revealed that the neurological and physiological foundations of the concept are strongly aimed at its extreme profit. It is said that biophilic design benefits humans and nature's needs, it aims to reduce stress, improve cognitive performance, and support positive emotions and mood. (Dias, 2015)

agricultural waste

The agricultural sector plays an important role in human and economic development. Recycling solid wastes, which a great amount is generated from the agricultural sector, could lead to the reduction of greenhouse gasses. Such green wastes can be easily shredded and reused to create new base materials in other sectors. (Adejumo and Adebiyi, 2020) Agricultural waste can be a great substrate component, full of nutrients for the bio-fabricated mycelium materials, without neither energy input nor extra waste generation. (Yang, Park and Quin, 2021)

Some examples of agricultural waste include crop residue, tree leaves, grass, hemp, old trees, sawdust, forest waste, grape stems, grains, root tubers, fruit peels, sugarcane bagasse, rice husks, cotton stalks, straw, and stover.

outdoor schooling

child-centered learning process

Outdoor schooling is a learner-oriented programme, which takes place in the natural environment aiming for the creation of a long-lasting relationship between the learner and nature. (Tonicha, David and Nic, 2014) Forest school sessions reach benefits crucial for society and the planet, marking a long-term change in learners' behaviour while expanding a unique relationship of humans with nature. (Knight, 2016) Forest school develops self-esteem and confidence through learner inspired, hands-on experiences in a natural setting, and helps learners develop emotional, social, spiritual, physical and intellectual skills. Forest school create a safe environment to expand the abilities in building self-belief, resilience, and independence and solve real-world issues here are risks in everything we do, and we grow by overcoming them. (Tonicha et al., 2014)

A study has shown a correlation between regular exposure to the natural world and healthy brain development and increased engagement in learning. (Selhub and Logan, 2014) The deficit of quality time outdoors translated into a lacked fundamental skills like coordination, grip strength, and balance. Studies show that outdoor school learners show lower levels of hyperactivity and inattention than preschoolers.Outdoor schools aim to be a solution, connecting the education with the development on other levels crucial for children. (Emslie, 2019)

“This is not just one of those wacky design things, this is the future of design. We’re moving from the machine age, to the digital age, to the organism age. Products will no longer just be manufactured; they will be grown, as we will be working with living organisms to open up a symbiotic material economy.”

Lisa White

biofabrication

designing with life

Biofabrication is a meeting point of design, science and technology. Introducing biology within architecture brings a whole new perspective and possibilities to the fabrication of the materials that we design our environment with. Biofabrication materials are considered to be less harmful to the environment than manmade materials as the process of factory fabrication is replaced with biological processes, where living organisms are growing the materials themselves. (Silvia, 2019) We can let biology produce efficiently sustainable materials and grow all kinds of structures, by designing fundamental conditions for them to grow. (Lee, 2020)


figure 1
[Mycelium Chair by Eric Klarenbeek]

figure 2
[The Growing Pavilion]


figure 3
[Silk pavilion by Neri Oxman]


figure 4
[Aguahoja by Neri Oxman]

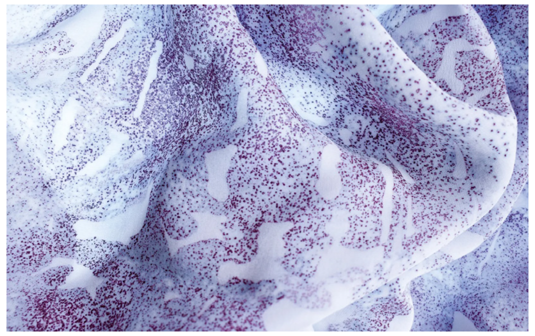


figure 5 [bacteria-dyed silk]

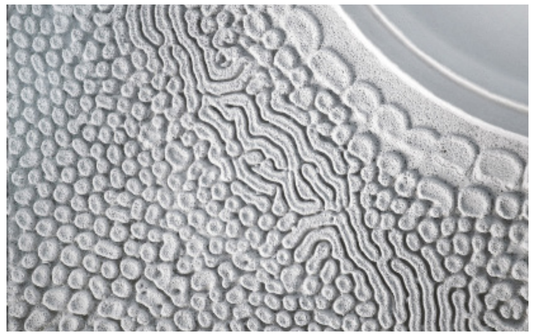


figure 6 [probiotic wall tiles]

references

"Nature is a much smarter architect than us,"
Carlo Ratti

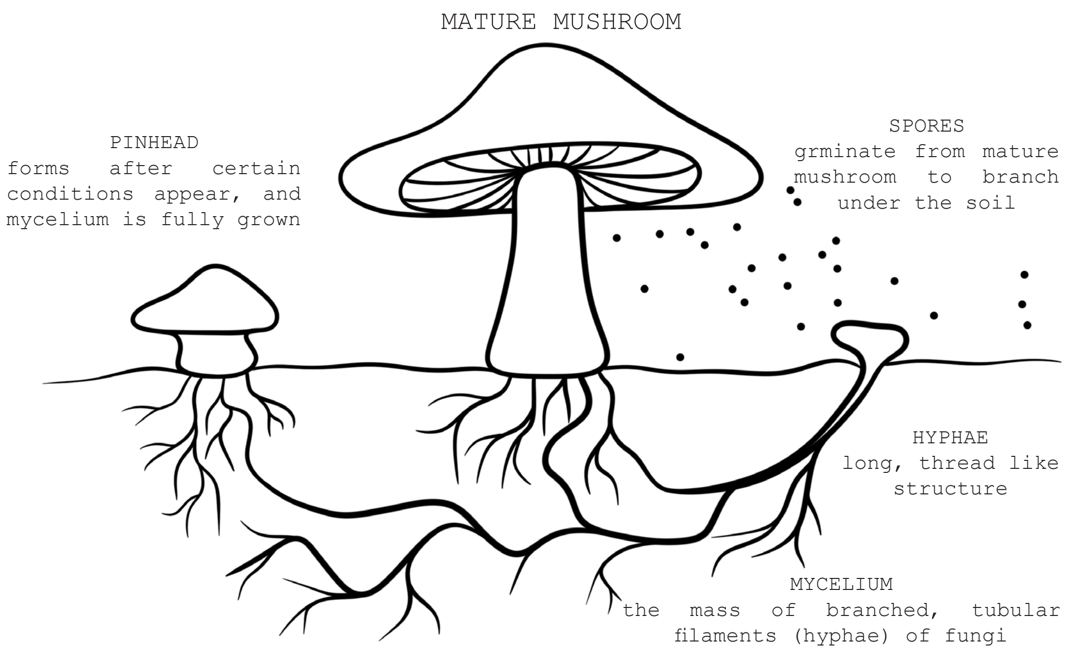
bacteria-dyed silk
Natsai Audrey Chieza is founder and CEO at Faber Futures.
Faber Futures focuses on biofabrication possibilities of bacteria, fungi and algae to develop new materials

probiotic wall tiles
Richard Beckett: Part of the NOTBAD project with Dr Sean Nair and Carolina Ramirez-Figueroa
"These probiotic wall tiles are biologically seeded with living bacterial cells that are able to inhibit the growth of MRSA. The tiles can reduce human exposure to pathogenic microbes and limit the spread of antimicrobial resistant bacteria in buildings."

the circural garden
CRA-Carlo Ratti Associati, in partnership with global energy company Eni, designed a self-supporting architectural mycelium arched structure for the Milan Design Week 2019. The installation consists of a series of arches, which are 1km long in total. The project exposes the beauty of temporary structures that are made with love for nature, can be grown organically with natural material and be returned to nature in a fully circular way.


figure 7

RESEARCH



mycelium

"Mushrooms are not like an animal, and not like a vegetable, but somewhere in between."

Eugenia Bone

Fungi start as spores and grow into mycelium which then generates mushrooms, (Ecovative) The mycelium of fungus refers to the fragile root-like fibres of fungus that live underneath the ground. (Saxton 2020) Fungi's root structure functions as a natural glue and can transform natural waste into solid biocomposites that can replace plastics and other CO2 emitting materials. Fungi can grow naturally hydrophobic materials and fire retardants without using any chemicals. (Silvia 2019) One of the most important disadvantages of mycelium composites is that their water resistance decreases over time, hence becoming vulnerable to mould and humidity. (Protopapadaki and Kalika, 2018) Moreover, when speaking about the degradation time, it takes only about 30 days for mycelium composites to naturally degrade, giving nutrients to the soil, while polystyrene needs thousands of years. (Silvia 2019) If the composite is kept in stable conditions, without touching the ground it can endure approximately 20 years. (Protopapadaki and Kalika, 2018)

100% biodegradable

fireresistant

waterproof

"Mother Nature has already provided the technologies that allow humans to be more efficient and sustainable."

Ecovative

mycelium

implementation examples

building material - hydrophobic, fire resistant, compression
acoustic composites
alternative to leather and synthetic textiles - 100% vegan and plastic free
compostable packaging
plant-based "meat" out of arimycelium
disposable healthcare products

We can allow the mycelium to grow a predictable structures by providing a designed mould. The mixture of mycelium with agricultural waste is being placed in the framework and placed in an environment with controlled temperature, humidity, and airflow. In about the week, the mycelium foam fills the mould creating a solid composite. When mycelium is fully grown, that's when the mushroom begins to grow. (Farrell, 2021) To stop the growing process of mycelium composite, the material is dried or heated. The drying process, lets the mycelium material grow again once the right conditions are established, while the heating process doesn't let the material regenerate and kills it permanently. (Ghazvinian, Farrokhsiar, Vieira, Pecchia, & Gursoy, 2019)

figure 8

DESIGN IMPLEMENTATION

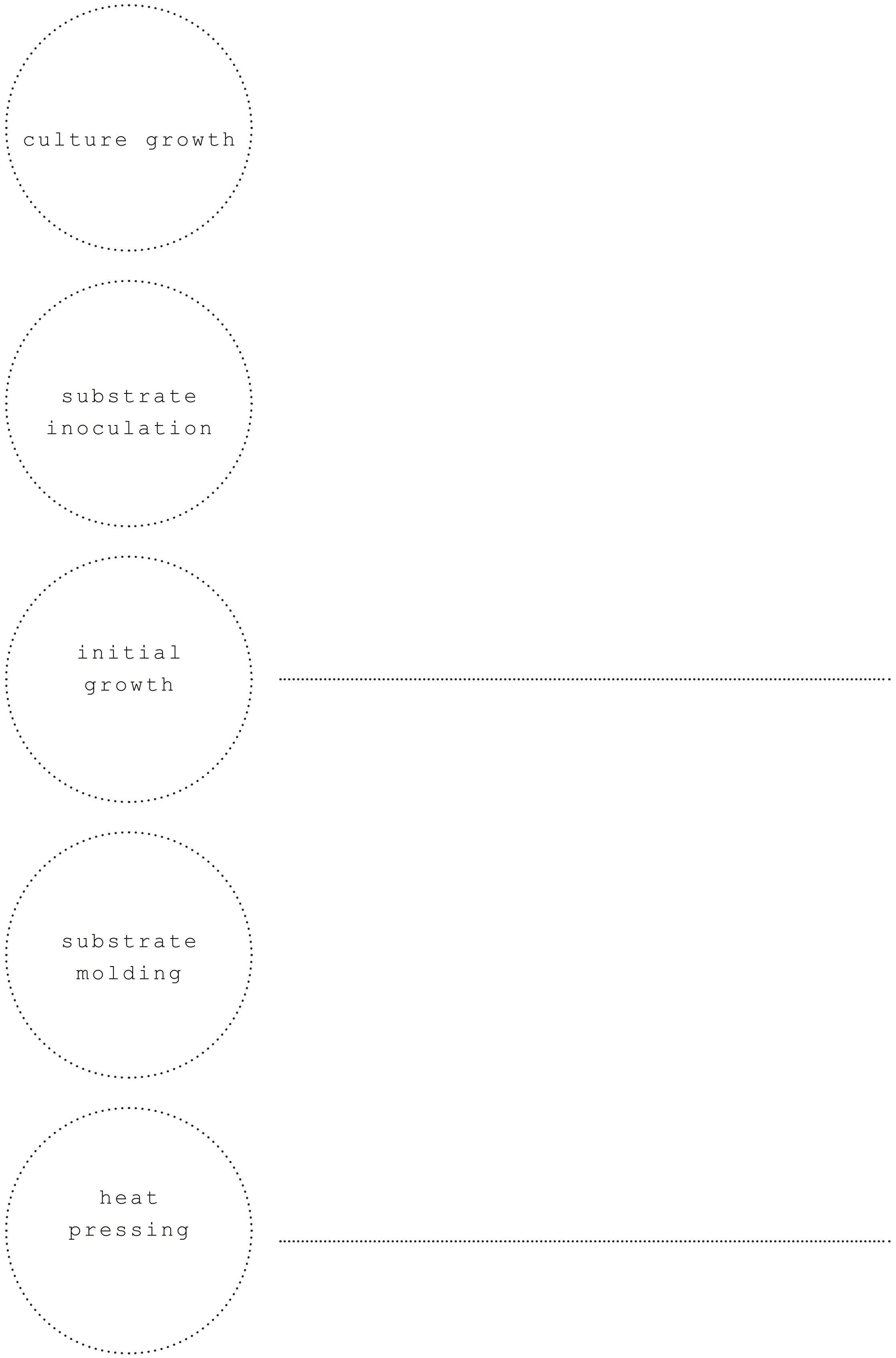
design implementation
outdoor pavilion

context
slottsskogen, gothenburg

The site selected for the pavilion is located in Slottsskogen, a park in central Gothenburg. The selection of the site was based on the position of the Gothenburg's preschool, which is located by the north-western border of Slottsskogen, which makes it both with Botaniska a very often visited place during the outdoor classes.

concept

The design implementation aims to present the research findings in the design of the outdoor learning pavilion. The goal is to present the tectonic and aesthetical properties of mycelium material. The design of the pavilion explores various textures delivered by mycelium, and its growth patterns over the bio-substrates. Since the growth of mycelium relies very much on the temperature, humidity and sun exposure, the pavilion's design makes use of mycelium's nature, reflecting its different stages of development.



pavilion structure

The whole structure of the pavilion is constructed with mycelium material, both living and dried, apart from the concrete base dividing the pavilion from the soil. Due to the natural process of mycelium materials decay, to provide a relatively long-lasting structure it is necessary to divide the dead and living parts from each other and the soil.

The sittings – alive part

Strain: bitter oyster-bioluminescence fungi

Production of the sitting structure, let the kids take an active part in the production process and learn about the lifecycle of bio-manufactured materials. The structure is kept in the living state, pre-grown in the lab until it reaches the ability to fight potential contaminants and is constructed on-site. The kids co-create the living part, by shaping it to the desired form. Due to the natural process of growth and decay, the structure is replaced annually. The disposed substrate can be reused, by supplementing with new nutrients and mycelium cultures.

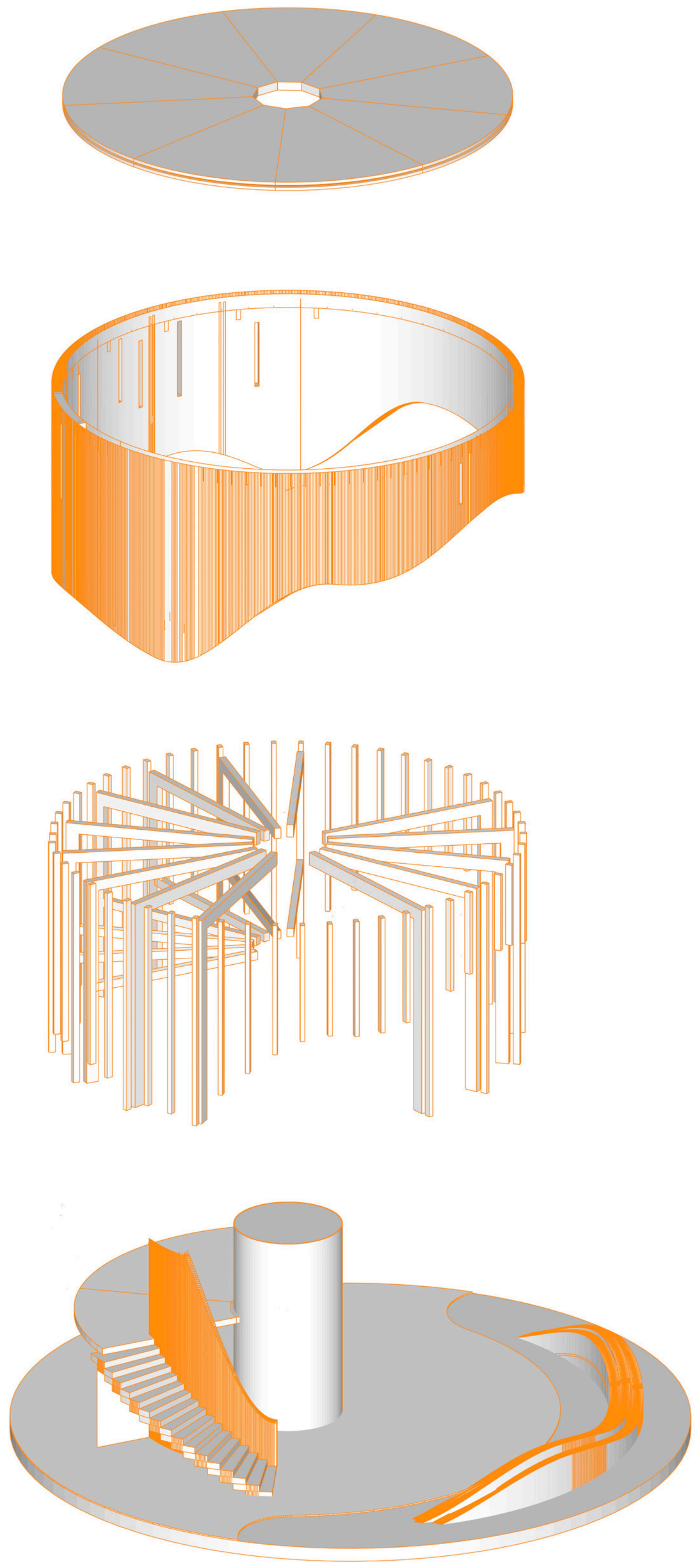
lifespan
~ 1 year

Pavilion - dried part

Strain: oyster mushroom

Structure pre-grown and dried in the lab, constructed on-site. The presence of various textures in the pavilion is controlled by different substrates and times of mycelium growth. Mycelium material is heat-pressed while drying to increase the strength and load-bearing capacity of the structure.

lifespan
~ 15 years



pavilion structure

roof

consists of 9 panels connected with two, running through them, wires creating a circle. The roof transfers the load to the beams and main pillar. The 1% roof slope drain rainwater to the outside.

18 side panels

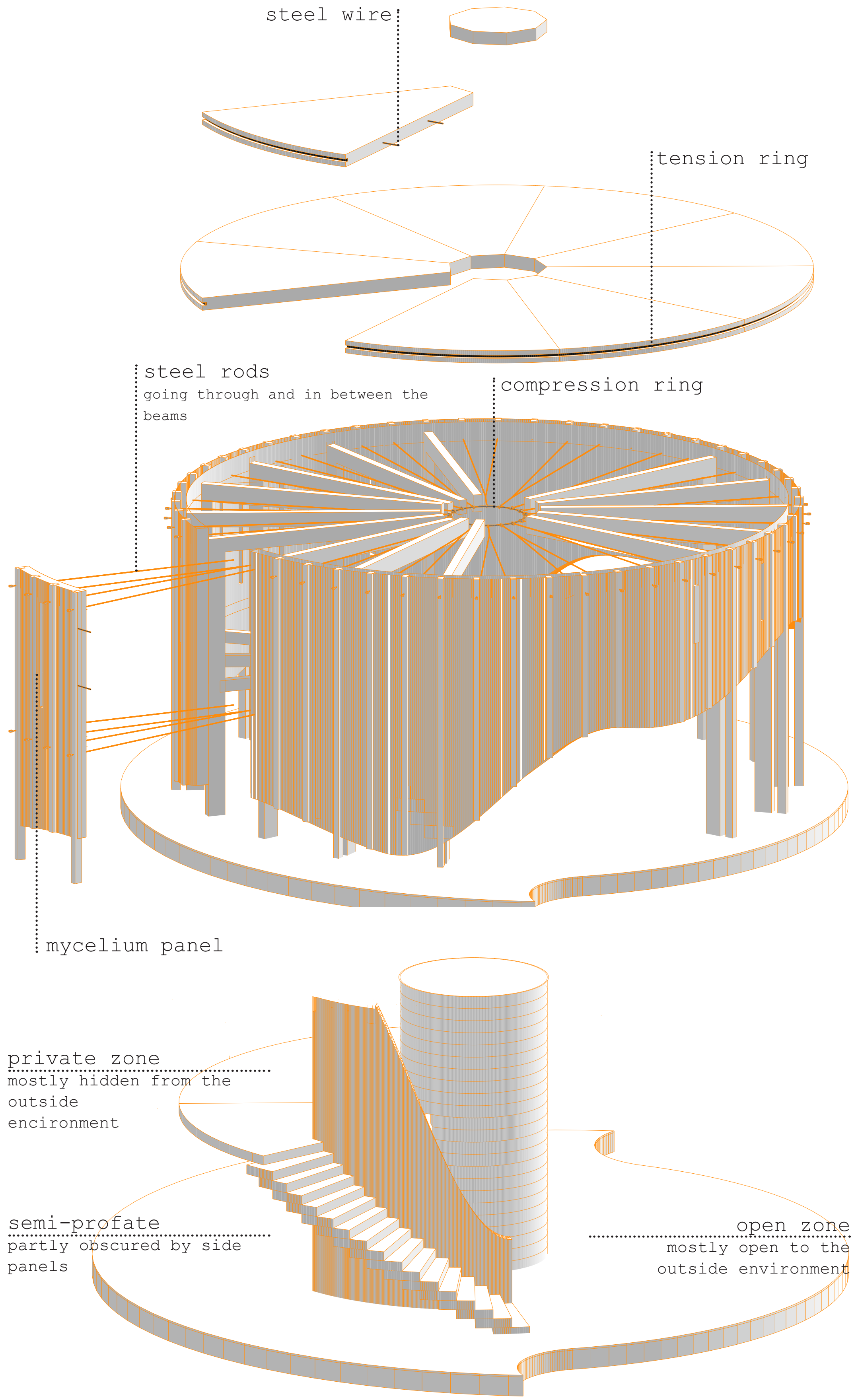
are connected and attached to the beams through a wiring system. The bottom edge of the surrounding panels regulates the openness and privacy level of the pavilion. The outside layer of the panels remains made of a uniform texture, while the interior of the pavilion presents a variety of mycelium texture possibilities.

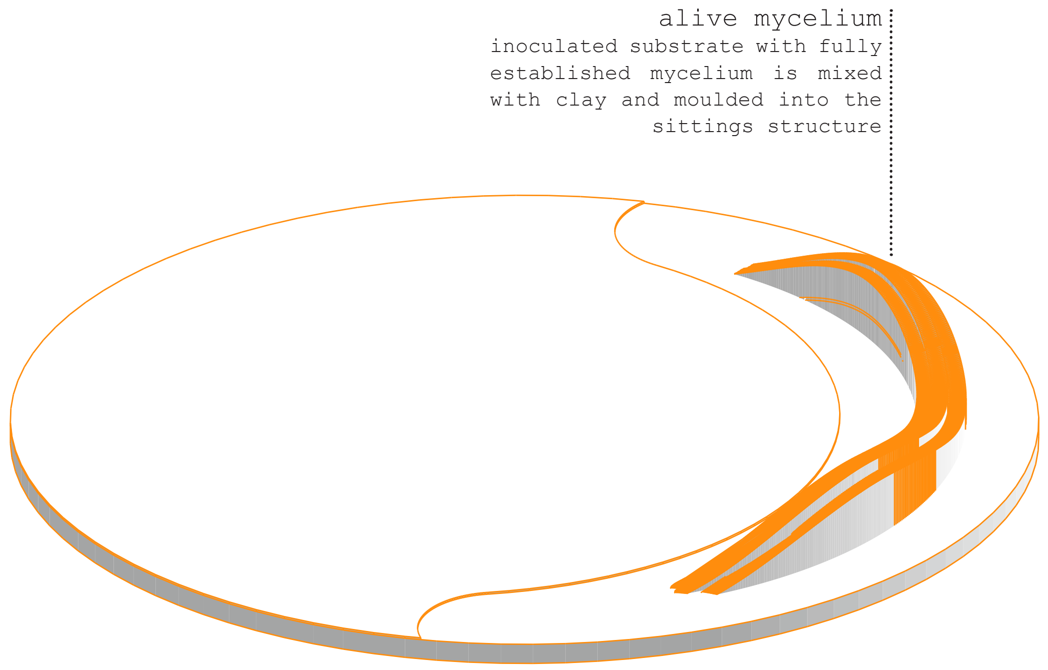
beam construction

supporting side panels and roof, connected with the base of the pavilion through the wiring system.

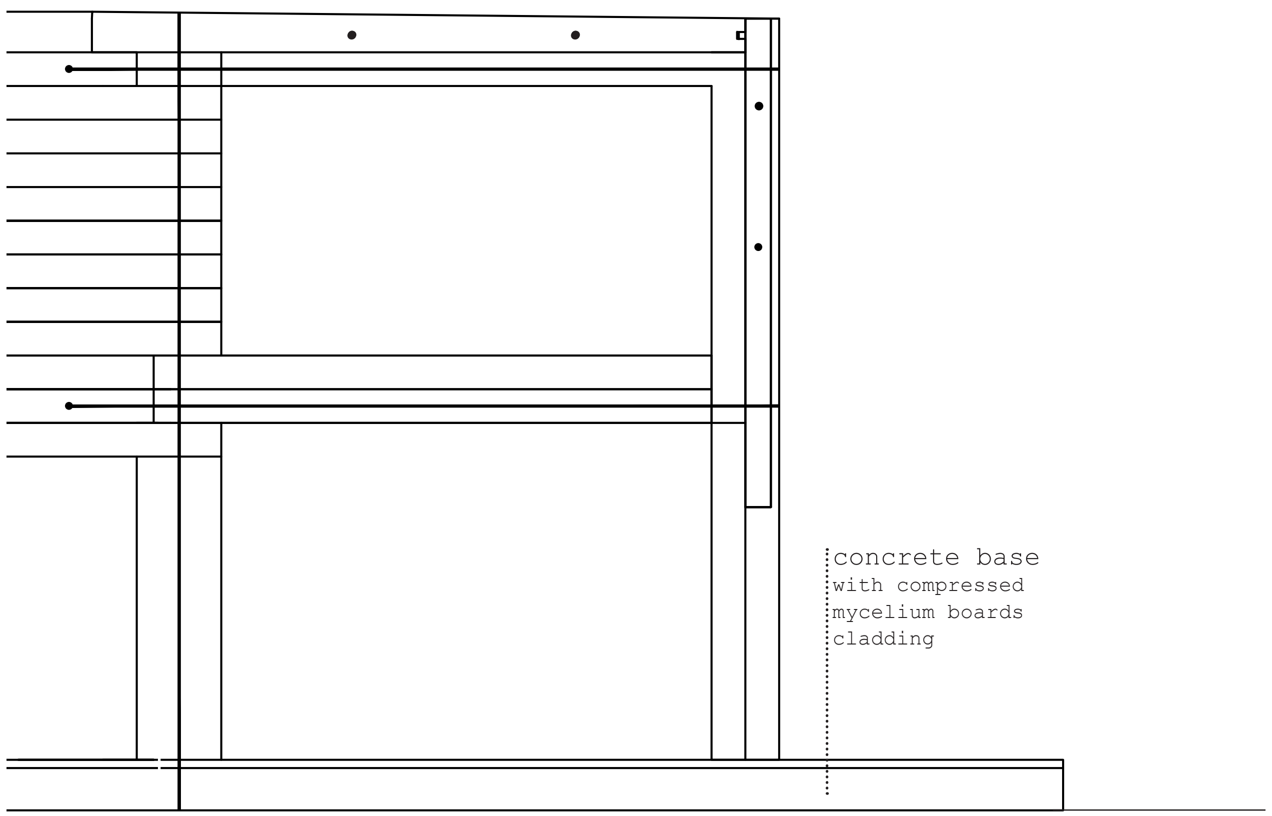
the base for the pavilion

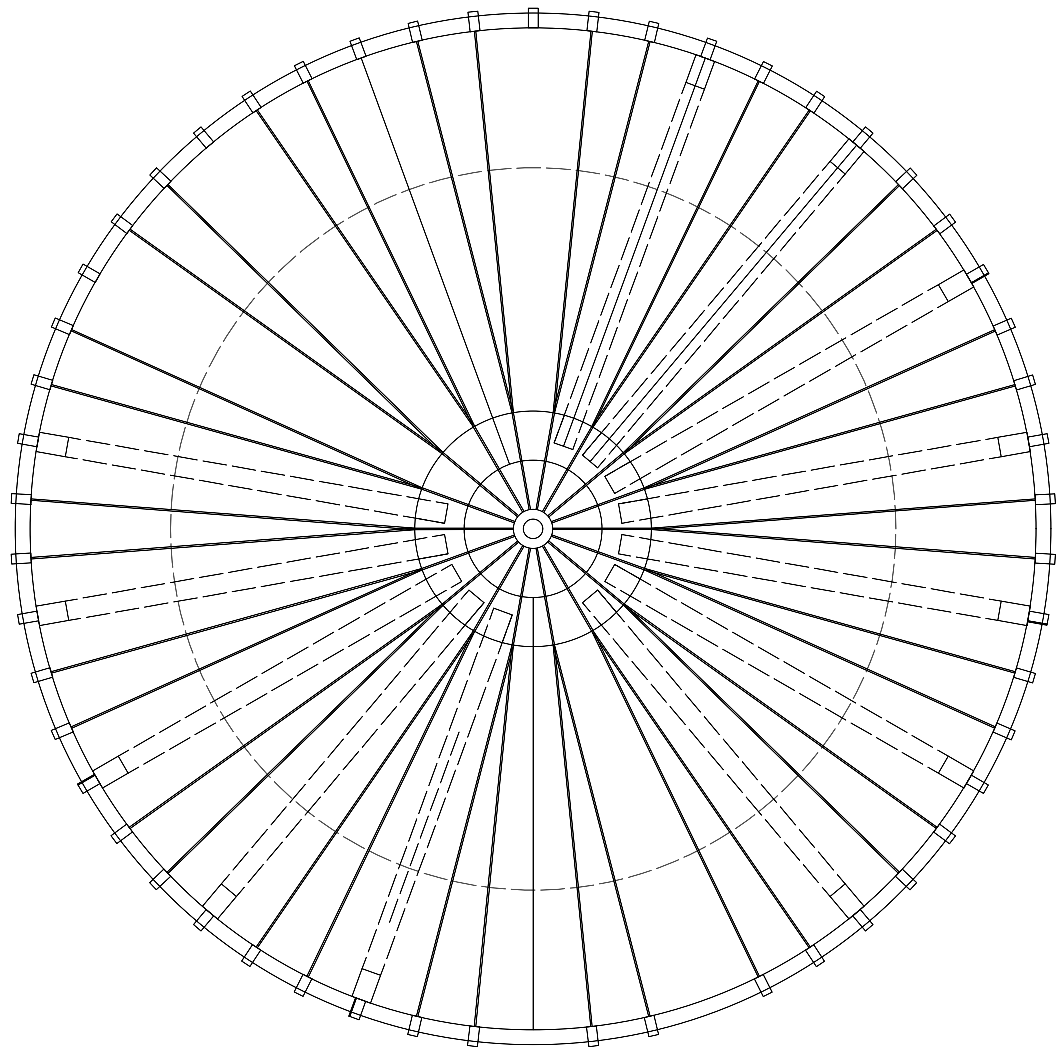
divides the whole structure from the soil to prevent decay. The main pillar, staircase and the beam are attached with the wiring system to the base.


steel wire
tension ring
steel rods
going through and in between the beams
compression ring
mycelium panel
private zone
mostly hidden from the outside encironment
semi-profate
partly obscured by side panels
open zone
mostly open to the outside environment


alive mycelium
inoculated substrate with fully established mycelium is mixed with clay and moulded into the sittings structure

dried part
construction





learning with textures

While mycelium gives the possibility of creating a variety of different textures of grown composites, the design application attempts to make use of those different textures as an education tool for preschoolers.

Exposing the kids to different textures will help them be more aware of the surrounded world. Even if they are not fully able to communicate verbally, they will learn how different textures and shapes feels like in touch and how they influence their feelings. The same thing applies to the sounds that might be heard in different environments and different seasons. Another valid reason for learning with textures is that it helps kids to build their own vocabulary, as they are not born with one to express the world around them. By associating different feelings with certain textures, the achers might help kids express those. (Webb, n.d.)

factors influencing the colour and texture of the material

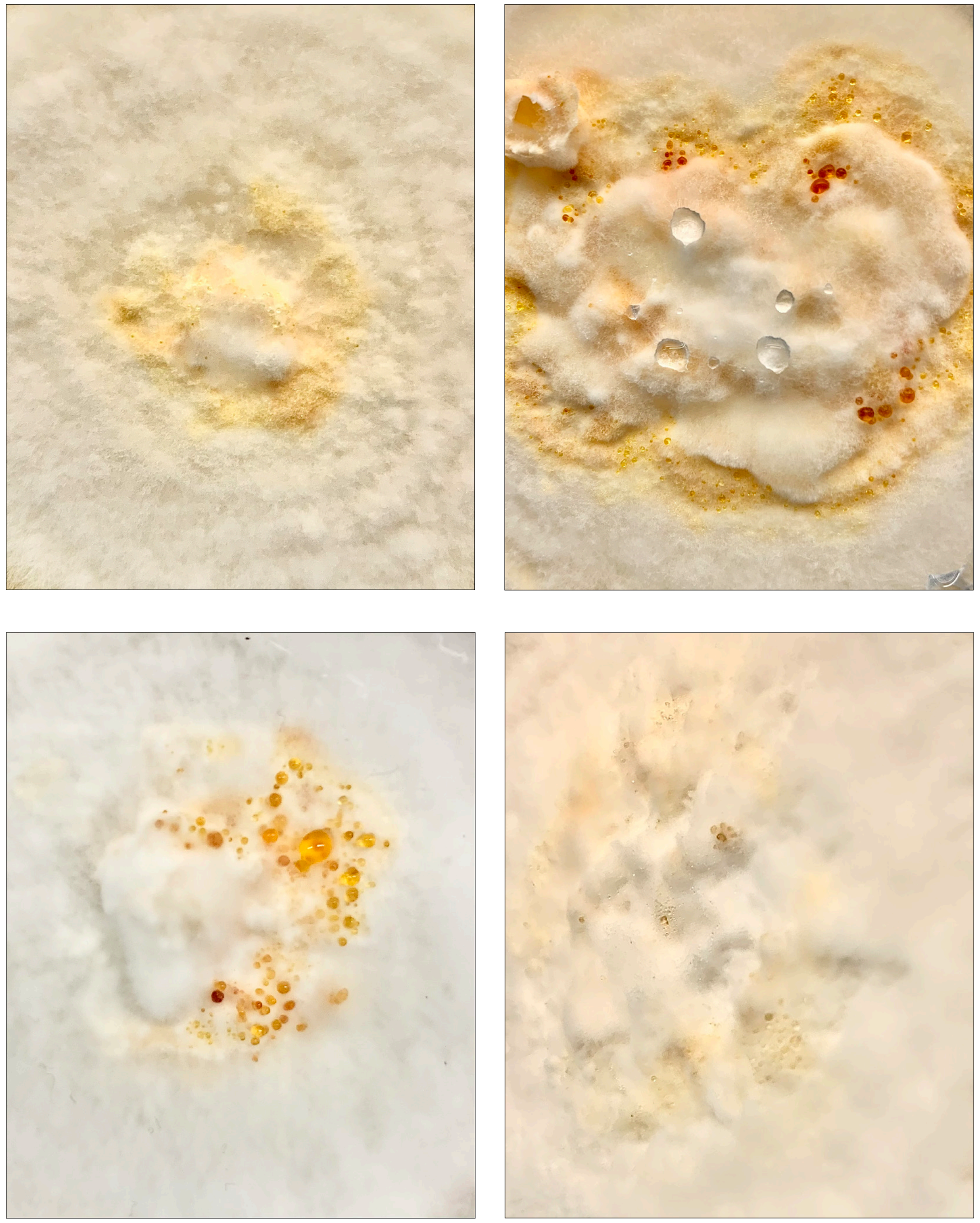
substrate

humidity

time of growth

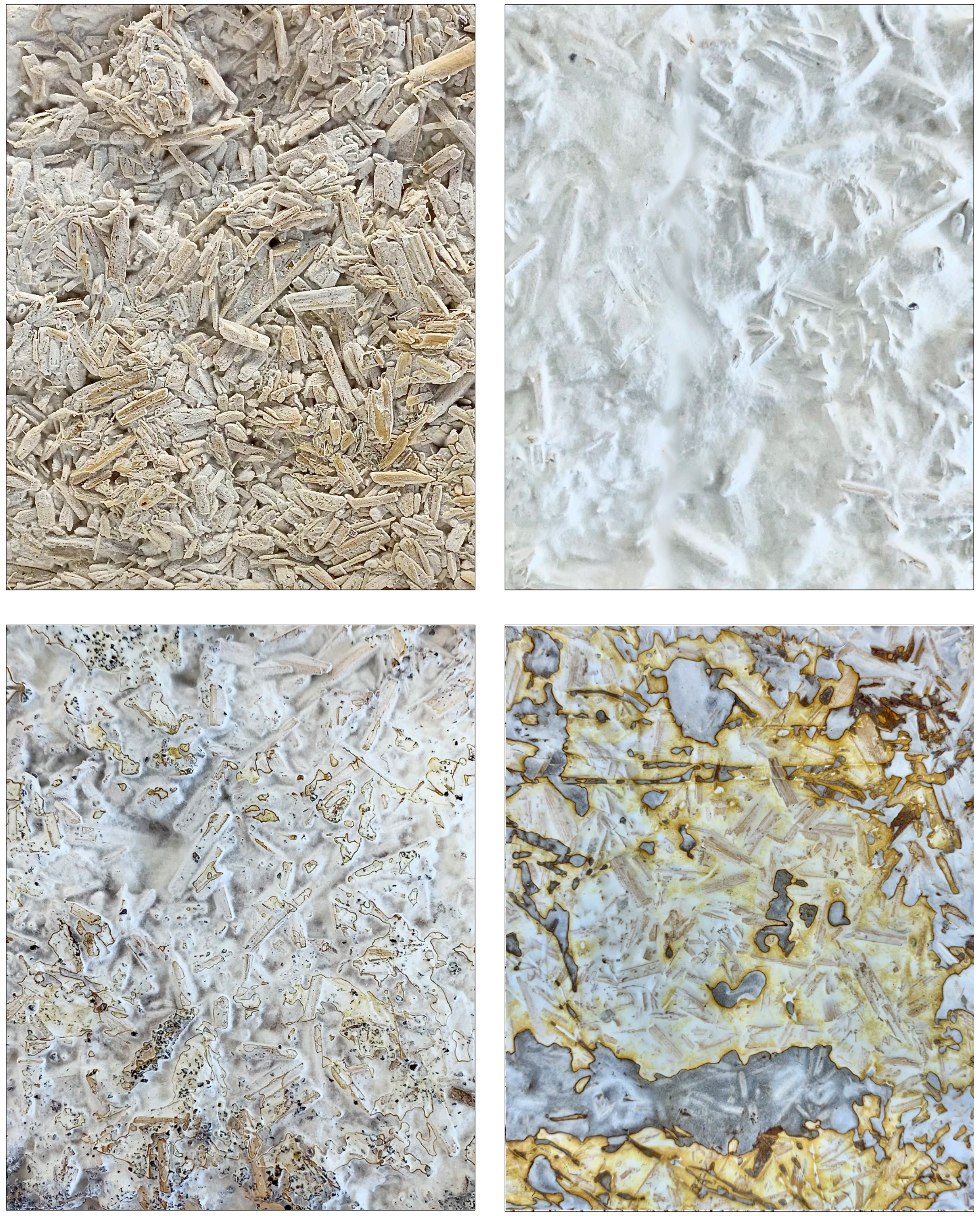
TEXTURES CATALOGUE

mycelium on agar

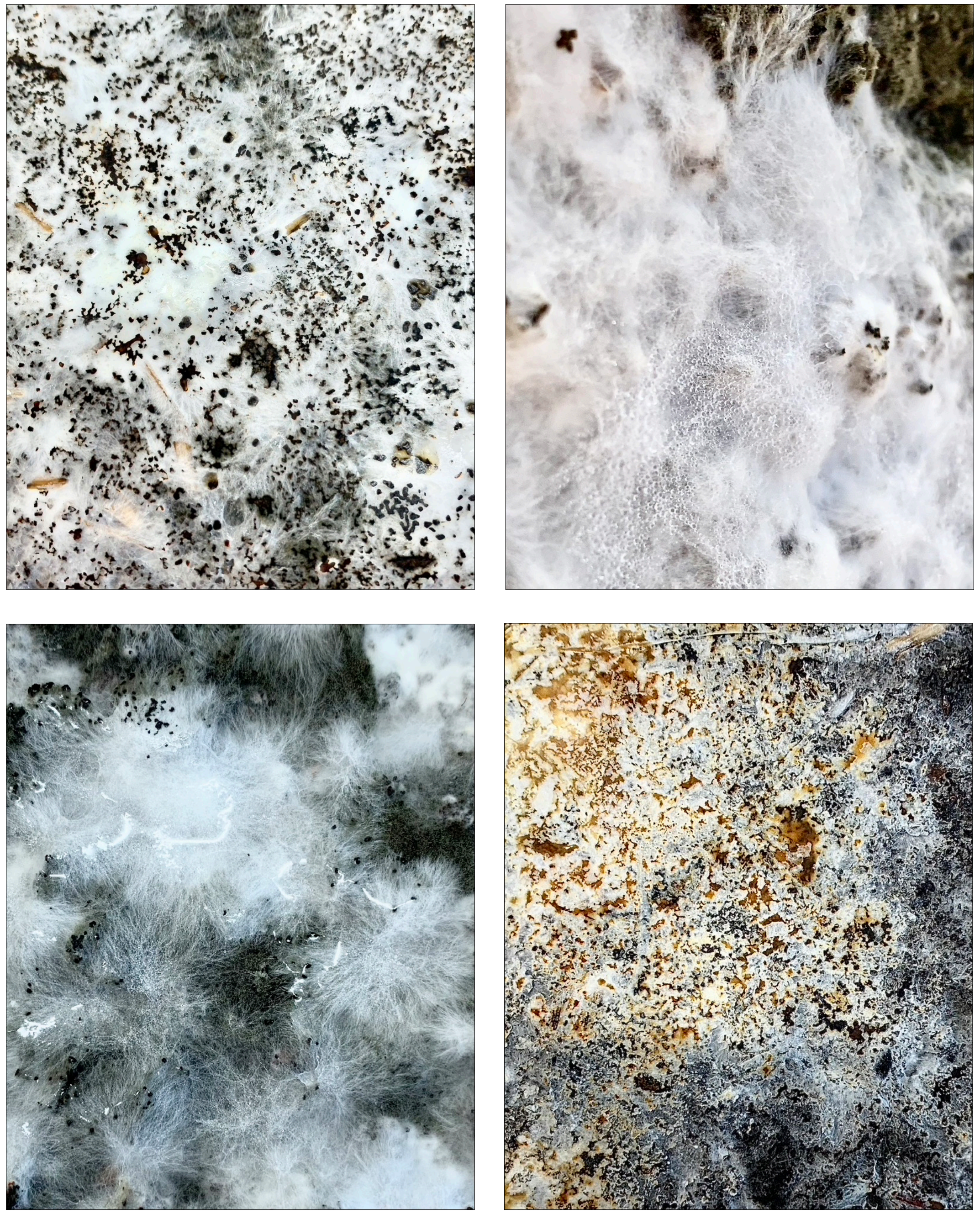


mycelium on wood

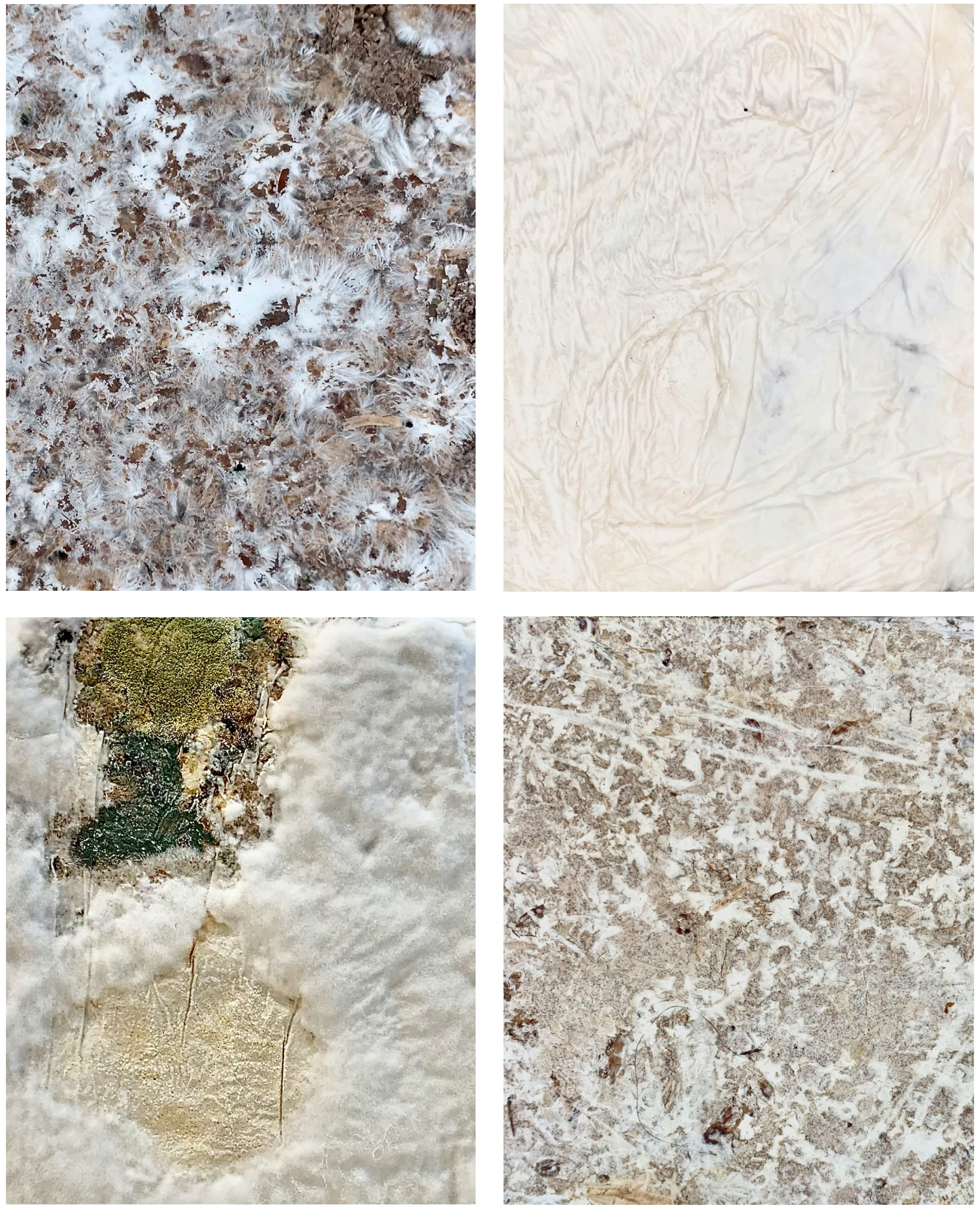
mycelium on hemp



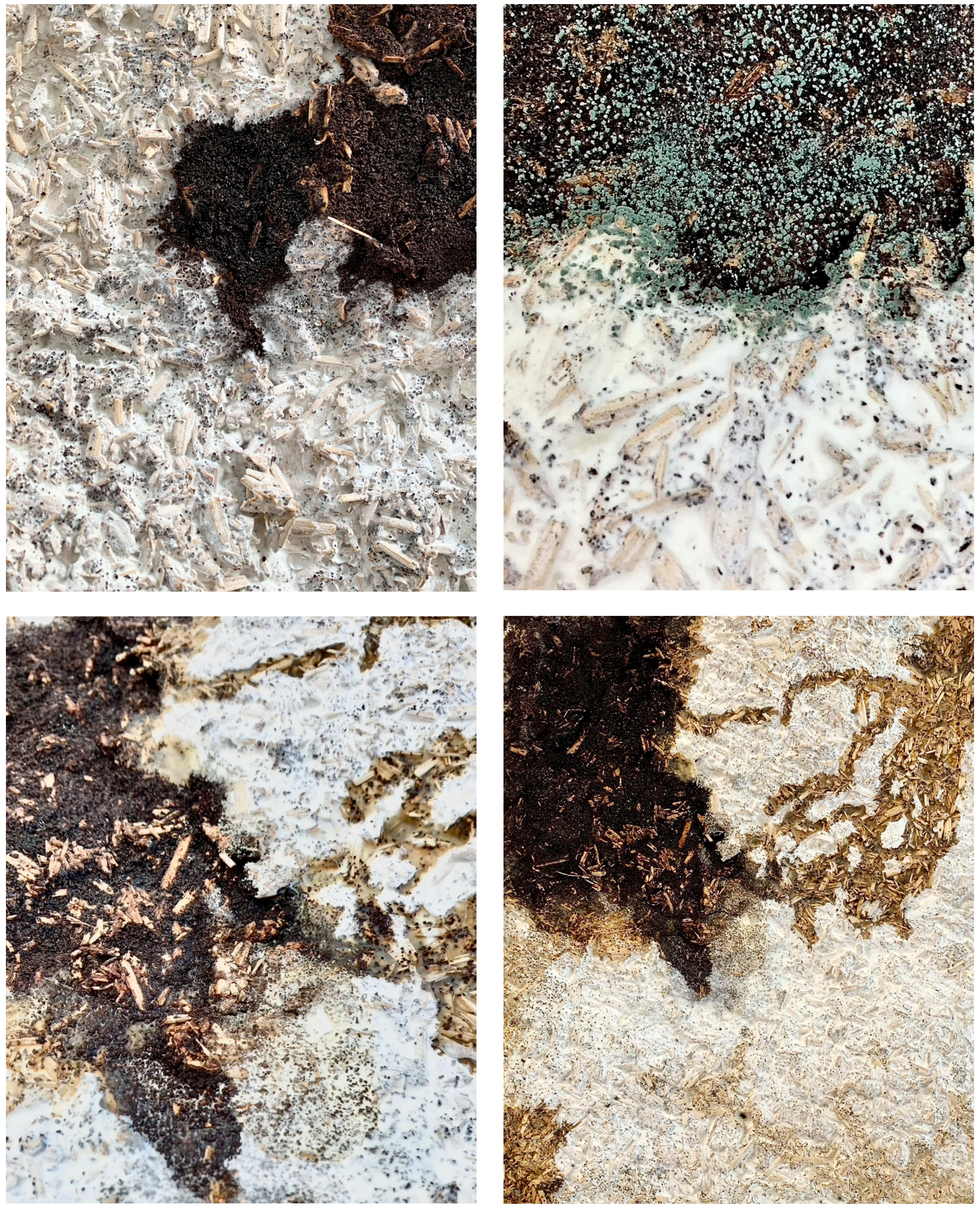
mycelium on coffee



mycelium on sawdust



mycelium on hemp + coffee






prototyping

1/18 part of the pavilion was grown in scale 1:5

reflection

The main purpose of this thesis was to explore the world of biofabrication , learn to grow mycelium material from scratch and elaborate further on its potential as a building material while designing a structure intended for an outdoor school programme. This thesis became a natural meeting point of the forest school paradigm and material study aiming for a sustainable future, where biologically driven research helped to find a way for humans and nature to coexist.

The experimentation and prototyping phase let to understand that the whole process was way more challenging in practice than it seemed to be in theory. When working with biofabrication, the most important part, the creation of the material, is placed in the “hands” of the living organism. For a person with no biological background, it felt like having control over the material is not possible. In the case of unsuccessful attempts in the experiments, when the material didn’t want to grow, although it seemed that everything was done within the framework, the only way to success was to deepen the research and retry the process to obtain a healthy composite in the final phase.

The given time framework allowed only a very small part of the possibilities of mycelium as a building material to be explored, however, the research phase has helped to understand the properties and vast potential of mycelium application not only in the architectural context. Therefore, the work became an endless process, and the pavilion design was just another step crowning some of the research and experiments findings leaving room for further investment and reflection.

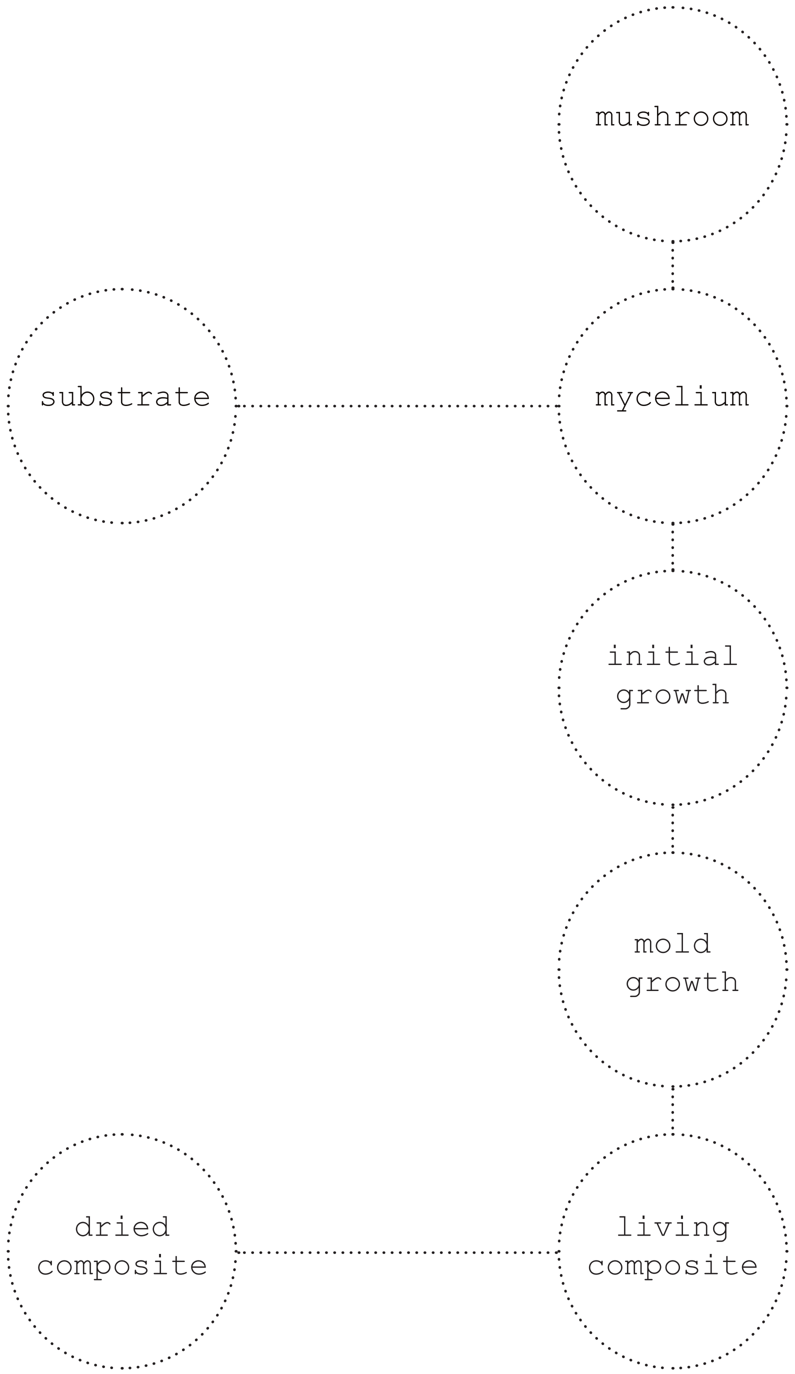
EXPERIMENTS

lab work

The lab works were carried out in the Industrial Biotechnology Laboratory at Chalmers. Most of the work was done in a sterile environment to avoid contamination of fungi and grown cultures and substrates. The experiments were conducted in a ventilated hood and ventilated lab bench. Petri dishes and bags with substrate and growing mycelium were kept in a dark place in a 30o incubation room.

Experiments were conducted to explore the qualities and techniques of creating mycelium structures based on various base materials: sawdust, coffee grounds, banana peels, hemp and rye. For the laboratory work, the Pleurotus Ostreatus (oyster mushroom) and Panellus stipticus (bitter oyster) were chosen. Pleurotus Ostreatus is very aggressive and can colonize a wide variety of substrate materials.

scheme



mycelium culture growth

procedure

1. Mushroom strain selection
Oyster mushroom

2. Obtain the mycelium culture
Mycelium culture can be obtained from the fruiting body of the mushroom
Prepare:
fresh mushroom
agar plates
scalpel, tweezers, ethanol, alcohol sanitiser
Cut the mushroom tissue from the inside of the fruiting body and place it in the agar medium. Leave it in the 30-degree incubation room for around 3 days

3. Mycelium subculture growth
Cut a small piece of mycelia plug and place it inversely into the agar plate, incubate for another 7-10 days.

4. Substrate sterilization
Place the substrate in the special filtered plastic bags, and sterilize in the autoclave.

5. Inoculation process
Cut the agar plate with grown mycelia into small pieces, and place it into the bags with the sterilized substrate. Add water and flour, close the bags and incubate for 7 days.

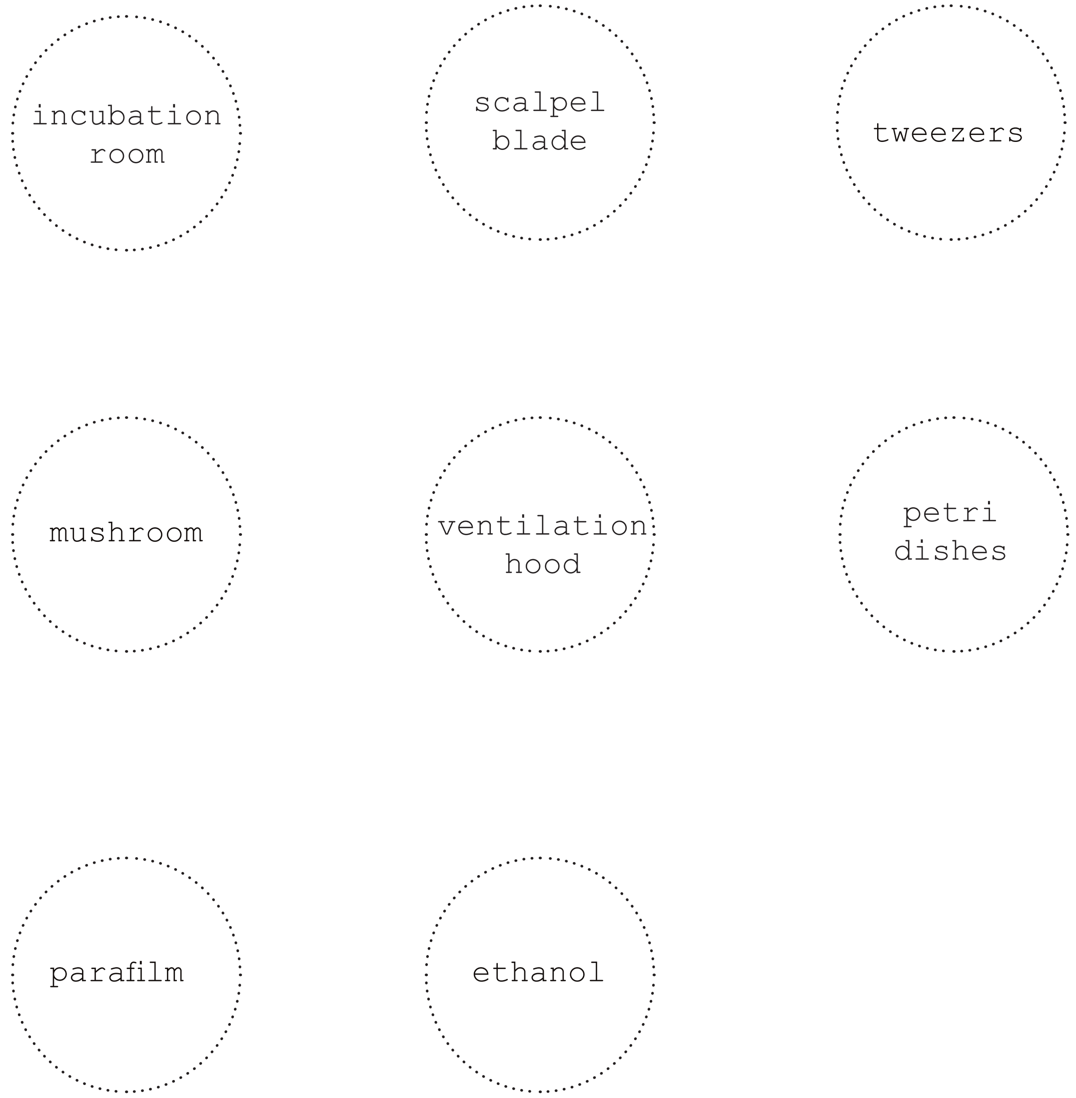
6. Moulding the composite
The inoculated mycelium substrate is placed into the sterilized plastic mould and is left for another week to fully grow and create a solid composite.

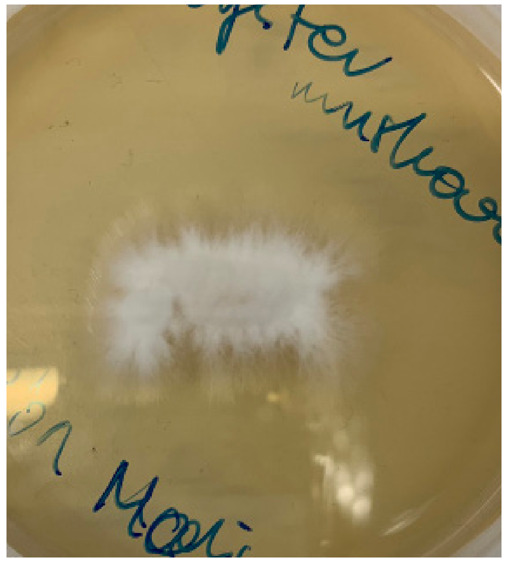
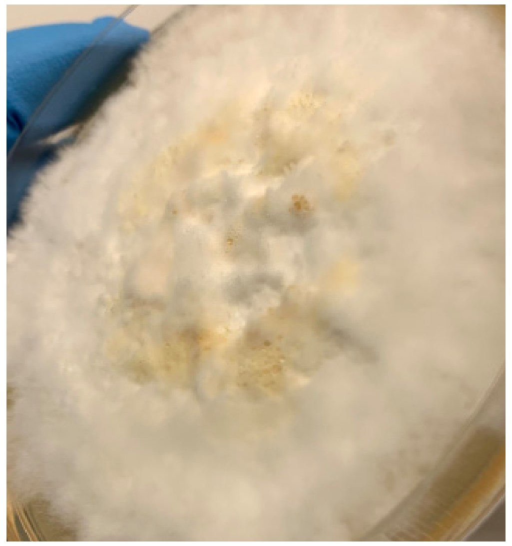
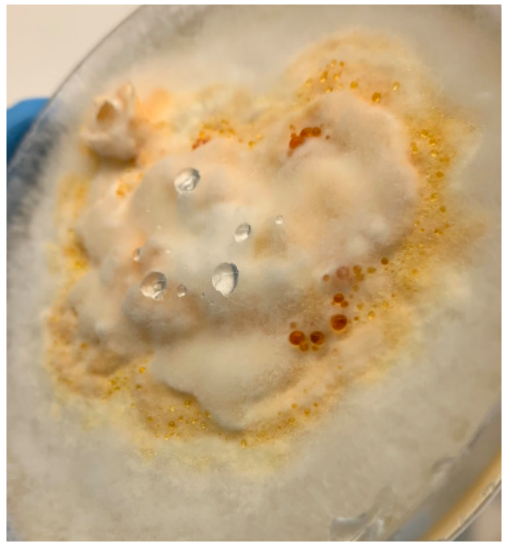
7. Drying
The composite is heat dried or heat pressed to achieve the desired stiffness of the material and stop the growing process of mycelia.

8. Living state
The composite can be left without drying to grow the fruiting body.

EXPERIMENT 1.0

mycelium culture growth
lab equipment



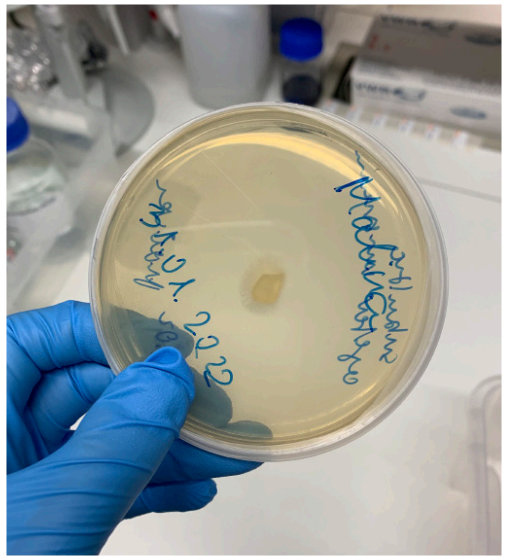
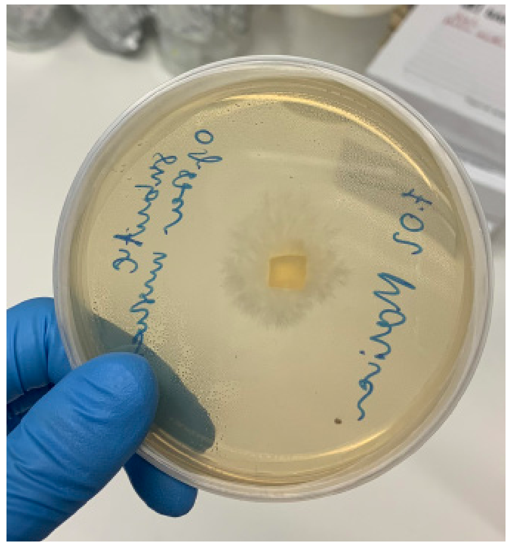
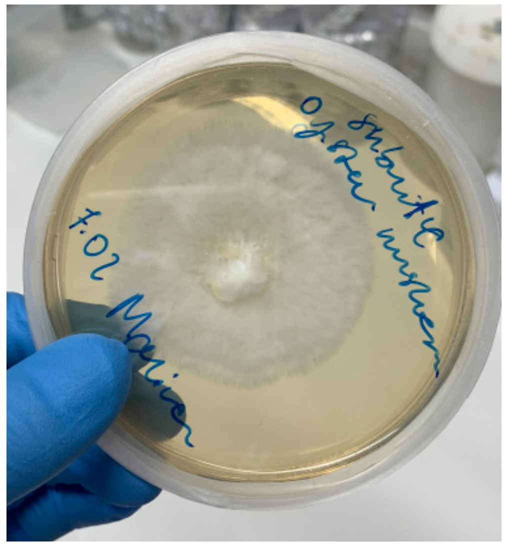
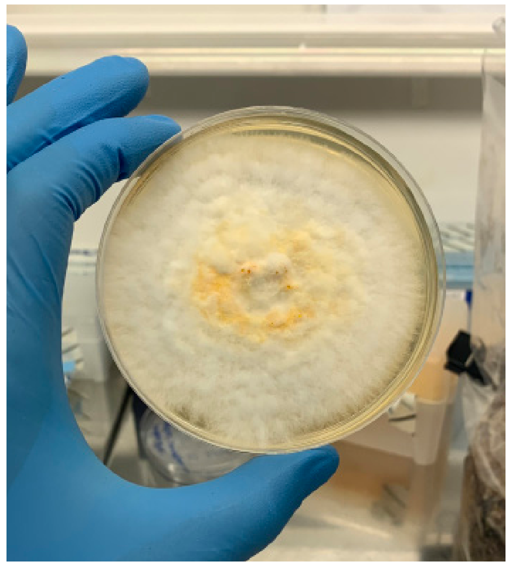
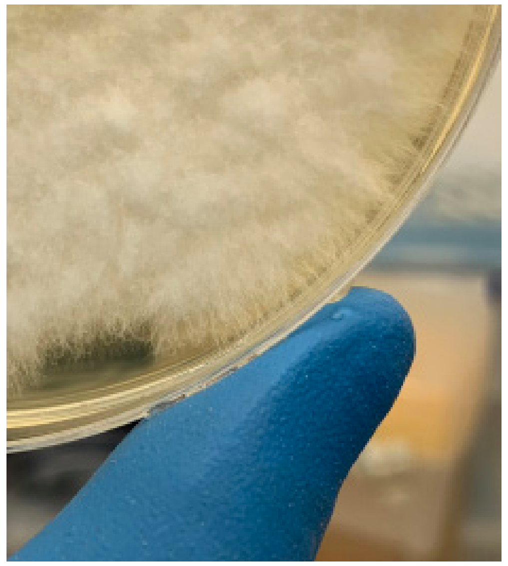
EXPERIMENT 1.0

mycelium culture growth
lab equipment

medium: agar plates
strain: Pleurotus Ostreatus

process:
Wear gloves and lab coat. Clean the ventilated hood area with 70% ethanol. Place petri dishes, container with fungi, scalpel blade, ethanol bottole, tweezers and parafilm in the ventilated hood. Sterilize your hands with 70% ethanol. Take one fuitting body of Pleurotus Ostreatus and tear it in half to expose the mushroom's tissue. Take the scalpel blade and cut a small piece of the mushroom's tissue. Use the tweezers to transfer mushrooms's tissue into the agar plate. Close the plate with the lid and seal the plate with parafilm. Repeat the process one more time and label two petri dishes with your name and date. Place the dishes in the 30° incubation room in shadow, under the shelf.

observations:
After one day the mushrooms culture started being covered with the white fluffy mycelium. After 3 days the whole mushroom's culture was covered with mycelium and started to spread on the agar.After 7 days, mycelium was ready for the next step (sub culture growth). After Experiment 1.1 the plates with mushroom's culture were turn back to the incubator for further observation purpose. After 11 days the dishes were placed in the paper box to provide a dark environment. On the 14th day, the vivid orange colour appeared on both mycelium structures. After a deep research it turned out that it was not contamination, as it was assumed in the beginning, but metabolites produced my mycelium. Metabolites consist of acids, exopolysaccharides, waste products and antibiotics, which are naturally secreted by mycelium cells. Metabolites production might be understood as stress reaction due to: lack of fresh air exchange, direct sunlight, high temperature, mycelium damage, defense from pathogenic microorganisms. Due to the above reasons, the paper box was opened to allow fresh air exchange. After 3 days the orange colour became less saturated.

EXPERIMENT 1.1

mycelium subculture growth
lab equipment

medium: 2% malt agar
strain: Pleurotus Ostreatus

process:
Wear gloves and lab coat. Clean the ventilated hood area with 70% ethanol. Place petri dishes with grown mycelium culture, scalpel blade, ethanol bottole, tweezers and parafilm in the ventilated hood. Sterilize your hands with 70% ethanol. Take the scalpel blade and cut a small piece of the mycelium culture with agar. Use the tweezers to transfer the muycelium into the new agar plate. Close the plate with the lid and seal the plate with parafilm. Repeat the process a few times. Place the dishes in the 30º incubation room in shadow, under the shelf.

Observe the plates for the next two weeks. When the mycelium covers the whole plate, it is ready for the next step.

EXPERIMENT 2.0

substrate inoculation

lab equipment

substrate

glass bottles

mycelium subcultures

bags with filter

scalpel blade

ethanol

autoclave

sterile water

flower



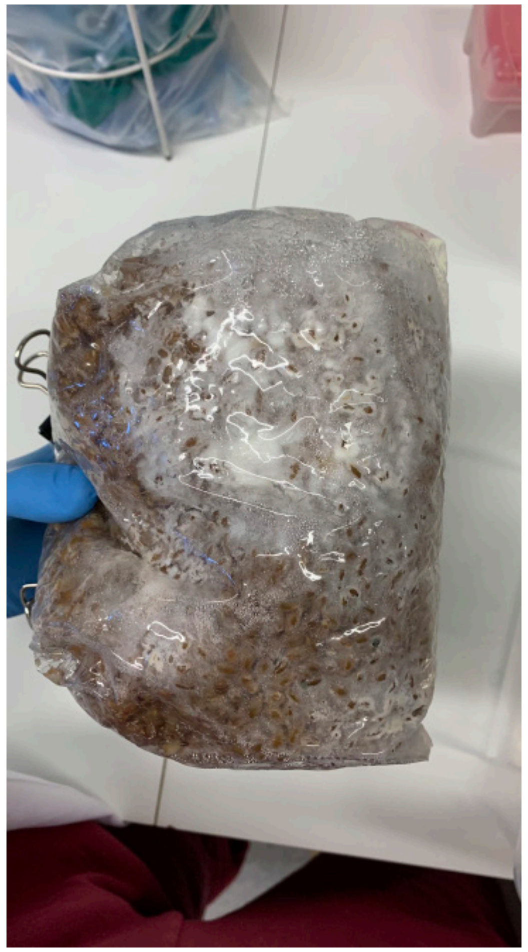

EXPERIMENT 2.0

substrate inoculaiton
polypropylene culvation bags

medium: sawdust, banana peels, coffee grounds
strain: Pleurotus Ostreatus

process:
Wear gloves and lab coat. Place the substrates mixed with flour in the glass bottles, autoclave for 1 hour. Move the substrate to the polypropylene cultivation bags, close the bags with clips. Clean the ventilated hood area with 70% ethanol. Place petri dishes with grown mycelium subculture, scalpel blades, bags with substrate , sterile water and parafilm in the ventilated hood. Sterilize your hands with 70% ethanol. Open the bags and pour sterile water. Open the petri dishes and cut the mycelium into the small-squared parts. Place the mycelium with agar into the bags. Close the bags with clips and shake the bags to spread the water and mycelium overt the whole substrate. Place the bags in well ventilated, room temperature environment.

observations:
After 7 days, no sign of growth observed. about 300-600ml of sterile water was added to each bag to increase the humidity. After a few days, growth of mycelium was observed in a few spots in sawdust. Green mold was observed in the bag with banana peels. No growth observed in coffe grounds. After another two weeks the green mould was observed in all of the bags, which had to be thrown away.



EXPERIMENT 2.1

substrate inoculaiton

medium: rye
strain: Pleurotus Ostreatus

process:
The bag with rye was sterilized earlier at home, boiled for 2 hours and moved to the lab.

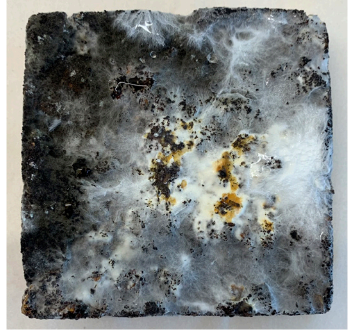
Wear gloves and lab coat. Clean the ventilated hood area with 70% ethanol. Place petri dish with grown mycelium subculture, scalpel blade, bag with substrate and parafilm in the ventilated hood. Sterilize your hands with 70% ethanol. Open the bag and petri dish. Cut the mycelium into the small-squared parts. Place the mycelium with agar into the bags. Close the bags with clips and shake the bags to spread the mycelium over the whole substrate. Place the bags in 30° incubation room.

observations:

Mycelium growth observed already after one day.
After 2 weeks the bag was fully grown, and mycelium rye spawn will be further grown in coffee grounds and sawdust.





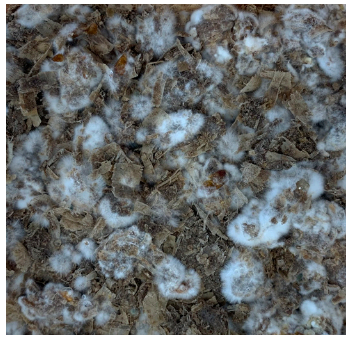

EXPERIMENT 3.0

substrate moulding

medium: coffee
strain: Pleurotus Ostreatus

PROCESS:
Prepare rectangular molds using EPS. Wear glowes and sterilize your them with 70% ethanol. Wipe the mold and working area with 70% ethanol. Open the bag with inoculated rye grains, connect a small piece of the mixture with previously pasterized coffee grounds and gently place the mixture into the molds. Cover the molds with plastic foil and secure with clips. Make a tin holes in the foil to provide air flow.

The samples has been taken out of the molds after 3 weeks and left to dry in the room temperature. The samles gradually shrinked over time and seemed to be very brittle.



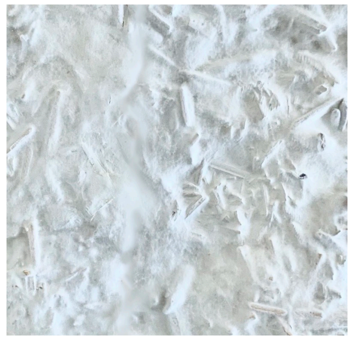

EXPERIMENT 3.1

substrate moulding

medium: sawdust
strain: Pleurotus Ostreatus

process:
Prepare rectangular molds using EPS. Wear glowes and sterilize your them with 70% ethanol. Wipe the mold and working area with 70% ethanol. Open the bag with inoculated rye grains, connect a small piece of the mixture with previously pasterized sawdust and gently place the mixture into the molds. Cover the molds with plastic foil and secure with clips. Make a tin holes in the foil to provide air flow.

The samples has been taken out of the molds after 3 weeks and left to dry in the room temperature. The samples turned out very solid and durable in touch. One of the samples was pressed during the drying process. It's thickness decreased about 4 times, gained stiffness and remained almost like a piese of plywood.



EXPERIMENT 3.2

substrate moulding

material: growing kit from Grownbio

process:
Prepare rectangular molds using EPS. Wear glowes and sterilize your them with 70% ethanol. Wipe the mold and working area with 70% ethanol. Open the bag with growing kit, add flower as instructed. Gently place the mixture into the mold. Cover the mold with plastic foil and secure with clips. Make a tin holes in the foil to provide air flow.

After 5 days samples are ready to be taken out of the molds and be left to dry in the room temperature. One of the samples were left for further growth in the closed environment for another 3 days in order to get covered with soft mycelium "skin".

EXPERIMENT 4.0

growing patterns

mycelium culture growing over wood

EXPERIMENT 5.0

growing patterns

introducing coffee in the hemp panel growth

INTERVIEWS

outdoor preeschool

Gothenburgs Preschool

Söderlingsgatan 9 is split into three groups:

Discoverers (1-3 years), and Pioneers (3-5)

Gothenburgs Preschool Outdoor program (Söderlingsgatan) Mounties (4-5 years)

5 concepts that rule the preschool:

science and technology
nature
language
democracy
gender equality

Benefits learners get from outdoor program:

- Learn new outdoor skills and overcome new challenges
- Self regulation and self reflection skills
- Improved physical stamina, fine and gross motor skills
- Positive identity formation for individuals and communities
- Environmentally sustainable behaviors and ecological literacy (footprint)
- Increased knowledge of environment, increased frequency of visiting nature within families
- Health and safe risk-taking
- Improved creativity and resilience;
- Reduced stress and increased patience, self-discipline, capacity for attention, and recovery from mental fatigue
- Improved higher level cognitive skills
- Improved confidence, social skills, communication, motivation, and concentration

interview 1

WHO: Julie

"Teaching children is the most rewarding job. While they learn, children teach you how to see the world through their eyes and its the best exchange that can be"

CAREER: Outdoor teacher, Mounties program, Gothenburgs Preeschool

ABOUT: Outdoor schooling

DURATION: 30 min

When did you start working in this Gothenburgs preeschool and who started the outdoor programm?

I started to work in August 2017, when outdoor group didn't exist yet. It was created in 2018 by Joseph, the director of the preschool decided to crete that group, because he thought it would be great for his son, and other kids to have a fun year before going to primary school. He believed that we could learn a lot, we as a school we were already a lot outside, especially when the weather is nicer. We eat a lot outside. We are close to Slottsskogen that gives a lot of opportunities. We took teacher that's now at parental leave, that went to England to do a little crush course to see how's the outdoor school there, and when he come back he was blown away. Then the outdoor preschool started. He run this alone for the first year, because there were only 6 kids, but I joined him the second year, because the group developed. Now its my third year in Mounties.

Where are the kids from?

Sweden, America, Germany, India, England, Russia, Spainm Check republic and we are gonna have one from China soon.

Do you think outdoor programm is better than regular one?

Its not better, its different. I would say not all of the children are ready for it. They need to know whats what, before starting it, parents has to be really clearly informed abot the problem , because many of them was very schocked. They just sent the kids here, because its english speaking preeschool, without really knowing what outdoor preeschool is. It is a different approach, I like both. I like to mix outside and instide. Kids are more independent and their imagination is multiplied, because they dont have all the toys, and they have to create their own, which is really good.

Does thw kids that are not ready at the beginning for the outdoor program do they get easily adapted?

Yes, because they are children, they are resilient, they want to play, when they see their friends doing things, they want to join as well, they learn from each other. Some children don't grow with those skills, if the parents don't make their children walk, they don't have it from the start, so we do smaller walks, they get very tired fast, but then they get used to it. They are having fun tough, being in the mud, in the grass, snow, its fun for them.

What are the benefits?

They are getting more focused, they get curious about things, that you wouldn't think of. When they play in the classroom they have all the toys ready, but when we go outside and they see some leaves, they say "oh, it looks like a boat!" and they come back indoors and they say that they want to create a boat and they bring ideas from the nature. When we draw outside, they can draw for hours. Sometimes we say to take a mental picture, we go back inside and they gonna draw it.

How much time do you spend outside?

Outside, we spend between 3-5 hours, depending on the weather. In the summer we dont even go in. Sometimes we spend weeks without being in the classroom, we bring books, everything. Right now its a bit limmiting, also the clothes get wet, which make them cold, which they dont enjoy. We don't want them to feel miserable. SO as you see it looks a little bit in a winter. Currently we stopped cooking, usually we cook every wednesday, but right now they cannot have their glowes off to cut, so its very difficult for the hands. Outdoors they have to be focus all the time, and help each other. We also do other things outside, like math, counting, colours, music.. every two months we also change a theme. This month its about arts, but next month we start with science.

What are the things that you have to go inside for?

The toilet mostly. But other than that we can do everything outside. Here they have drawers, where they keep stuff that they can take outside. We dont have to be inside, but we do it when we see that they are very tired, because we can put them in a forest room, we have another toom that is more calm, quiet with different lighting, so they can relax. Yesterday we did a mindful session, some of them didn't want to, so they kept on playing legos.

What are their favorite things to do?

Climbing, pulling robes, balancing walk on the robe, they like to do the fire, painting, the free play is very important, because they bring ideas and create their own games, watching the animals on slotskogen.

What would be needed in a pavilion?

Building blocks, something that can stay there, but you dont have to bring it all the time. hooks, to hangs things, that children can go and take them theirself. Wall where you can attach the papers to paint. clibbing wall definetly, not to high, a little gym equipment for balancing, children are very energized, its good for them to use their bodies and learn control and muscles. The moving walls, by changing the level of privacy would give the posiibility to have a different setting but in the same place, because it changes the atmosphere. Sometimes when we go to the place where there are a big trees, we can run and be loud, but if we go to the place where are small trees, they are more quiet. It would be really good to be able to adapt the surrounding according to the atmosphere.

Do you use books to study writing and reading?

No, we create our own games, we follow twingle website and we print excercises.

What are the guildines and rules that describe outdoor preschool?

Balance outdoor and indoor, make sure that the children have fun, realize that being outside is fun and that you can actually learn from nature. We learn not only about the trees and animals, but also how to respect nature, which is a very goot thing. The mounties when they see trush, they alwys tell us, we have plastic bags so we can collect it. It opens the eyes in a different way. Everything they learn here it stays with them when they grow up. They learn how to take care for each other.

BIBLIOGRAPHY

Adejumo, I., & Adebiyi, O. (2020). Agricultural Solid Wastes: Causes, Effects, and Effective Management. IntechOpen. Retrieved 9 May 2022, from https://www.intechopen.com/chapters/73517.

Duarte Dias (2015), Beyond Sustainability - biophilic and regenerative design in architecture

Emslie, J. (2019). Are Outdoor Preschools Changing U.S. Education?. Retrieved 10 May 2022, from https://www.rei.com/blog/news/are-outdoor-preschools-the-wave-of-the-future.

Farrell, M. (2021). Is Mycelium Fungus the Plastic of the Future?. Youtube.com. Retrieved 10 May 2022, from https://www.youtube.com/watch?v=cApVVuuqLFY&t=36s.

Knight, S. (2016). Forest school in practice.

Lee, S. (2020). Why "biofabrication" is the next industrial revolution. Youtube.com. Retrieved 10 May 2022, from https://www.youtube.com/watch?v=7pMhqyteR5g.

Pawlyn, M. (2016). Biomimicry In Architecture (2nd ed.). Newcastle: RIBA Publishing.

Protopapadaki, I., & Kalika, S. (2018). BUILDING WITH MUSHROOMS. Critical Concrete. Retrieved 10 May 2022, from https://criticalconcrete.com/building-with-mushrooms/.

Saxton, M. (2020). Mycelium Fungi as a Building Material. Rise. Retrieved 9 May 2022, from https://www.buildwithrise.com/stories/mycelium-fungi-as-a-building-material.

Selhub, E. & Logan, A. (2014) Your Brain on Nature. Toronto: John Wiley & Sons

Silvia. (2019, June 14). Biophilic & Sustainable Interior Design · sustainable design: Biofabrication is the answer · DforDesign. DforDesign. Retrieved May 9, 2022, from https://dfordesign.style/blog/sustainable-design-biofabrication-is-the-answer

Tonicha, David, & Nic. (2014). What is Forest School? | Forest School Association. Forest School Association. Retrieved 9 May 2022, from https://forestschoolassociation.org/what-is-forest-school/.

Webb, N. Learning Through Textures: How and Why This is Important | Toddle About. Toddle About. Retrieved 9 May 2022, from https://www.toddleabout.co.uk/parenting/learning-through-textures/.

Yang, L., Park, D., & Quin, Z. (2021). Material Function of Mycelium-Based Bio-Composite: A Review. Retrieved 9 May 2022, from https://www.frontiersin.org/journals/materials.

FIGURES

Unless otherwise indicated, images and diagrams are made by the author.

figure 1
Mycelium Chair by Eric Klarenbeek. (2013). [Photograph]. https://www.dezeen.com/2013/10/20/mycelium-chair-by-eric-klarenbeek-is-3d-printed-with-living-fungus/

figure 2
Vinck, O. (2019). The Growing Pavilion [Phgotograph]. https://www.dezeen.com/2019/10/29/growing-pavilion-mycelium-dutch-design-week/

figure 3
Rory Stott. "Silk Pavilion / MIT Media Lab" (2013). ArchDaily. Accessed 2 Jun 2022. <https://www.archdaily.com/384271/silk-pavilion-mit-media-lab> ISSN 0719-8884

figure 4
Yiling Shen. (2018) "Neri Oxman and MIT Develop Programmable Biocomposites for Digital Fabrication" ArchDaily. Accessed 2 Jun 2022. <https://www.archdaily.com/894979/neri-oxman-and-mit-develop-programmable-biocomposites-for-digital-fabrication> ISSN 0719-8884

figure 5
Coulson, T. (2018). Silk dyed as part of Project Coelicolor [Photograph]. https://www.wired.co.uk/article/natsai-audrey-chieza-faber-futures-biodesign

figure 6
Beckett, R. (2021). Meso Scale Design of probiotic surfaces [Photograph]. https://www.ribaj.com/intelligence/presidents-awards-for-research-medal-winner-probiotic-design-microbes-in-buildings-for-health

figure 7
Ratti, C. (2019). The Circular Garden [Photograph]. https://carloratti.com/project/the-circular-garden/

figure 8
La Bianca, I. (2019). mycelium materials [Photograph]. https://www.materialincubator.com/building-on-mycelium