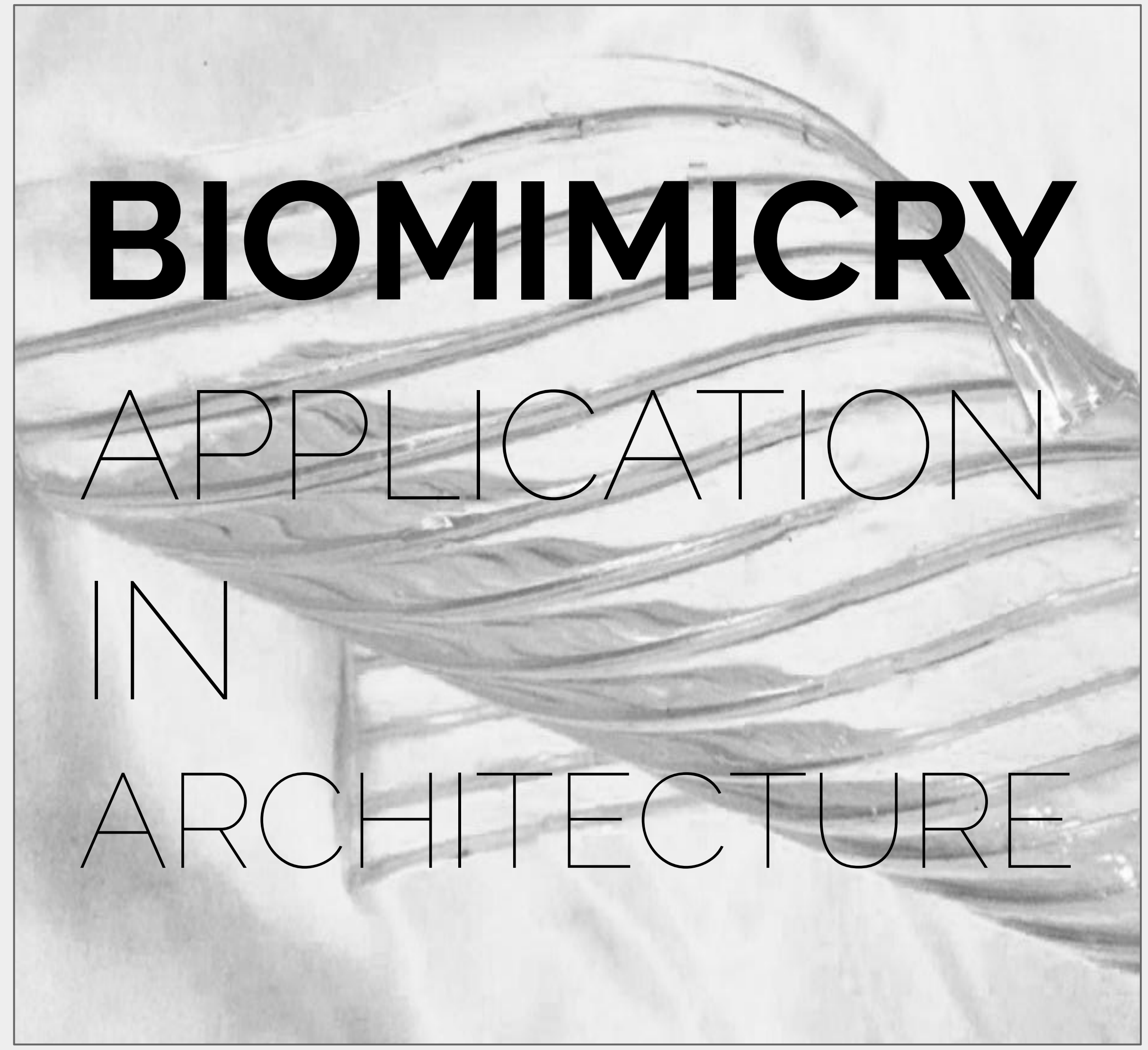
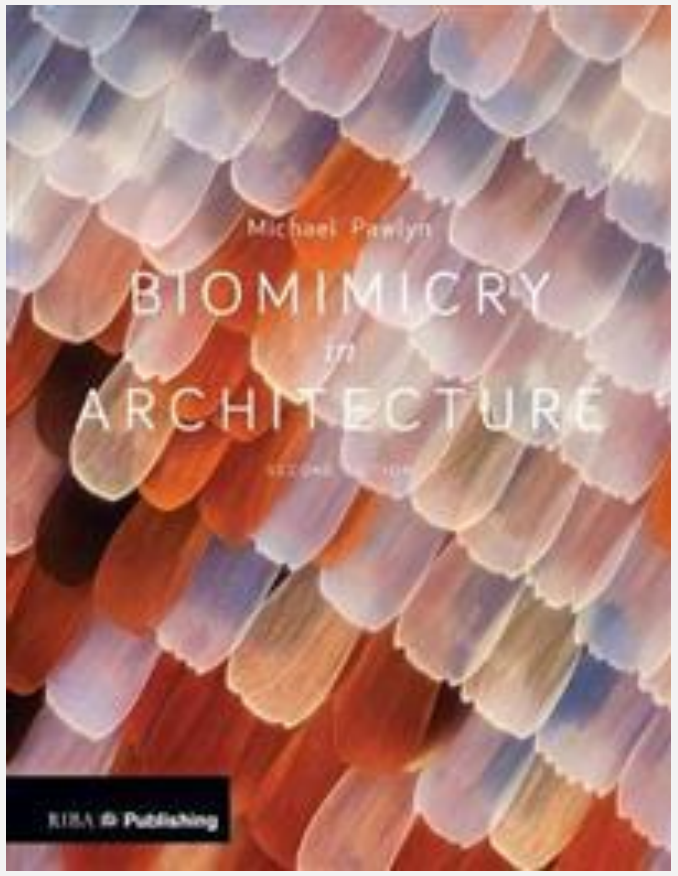
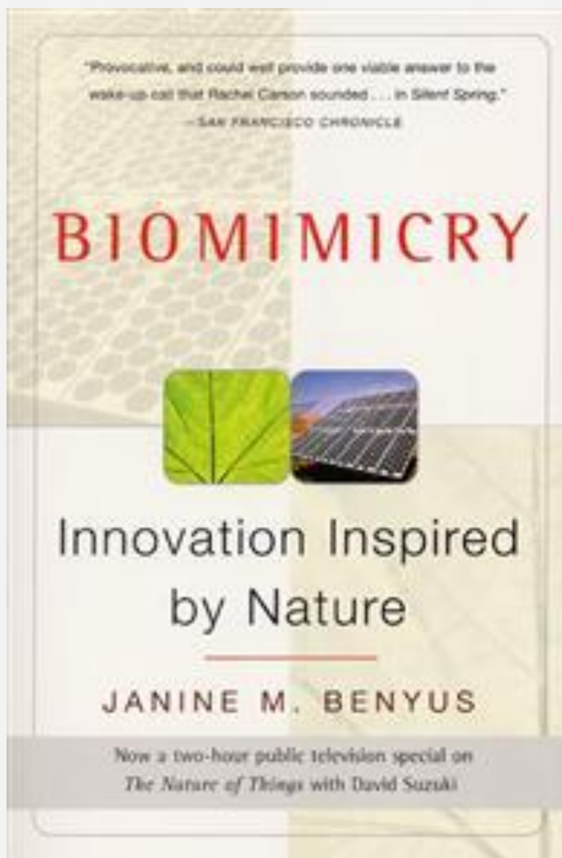


BIOMIMICRY APPLICATION IN ARCHITECTURE

REUSE a concept that exist in NATURE

Malina Tezycka | Ark 258 | MSS





DISCOURSE

Biomimicry is concerned with FUNCTIONAL solutions, and not necessarily focus on the aesthetic values.

The aim of this project is to explore the potential of biomimicry for designing valuable and useful structures for both human and other species use. The project wish to find a biomimicry concept that addresses the rain protection and water collection & storage, enabling creation of sheltered space for humans and other species need.

Research Question

How to translate adaptation in biology into solutions in architecture?

"If biomimicry increasingly shapes the built environment - and I feel it must - then, over the next few decades, we can create cities that are healthy for their occupants and regenerative to their hinterlands, buildings that use a fraction of the resources and are a pleasure to work or live in, and infrastructure that becomes integrated with natural systems."

"Biomimicry involves learning from a source of ideas that has benefitted from 3.8- bilion -year research and development period"

~Michael Pawlyn

THREE TYPES OF BIOMIMICRY

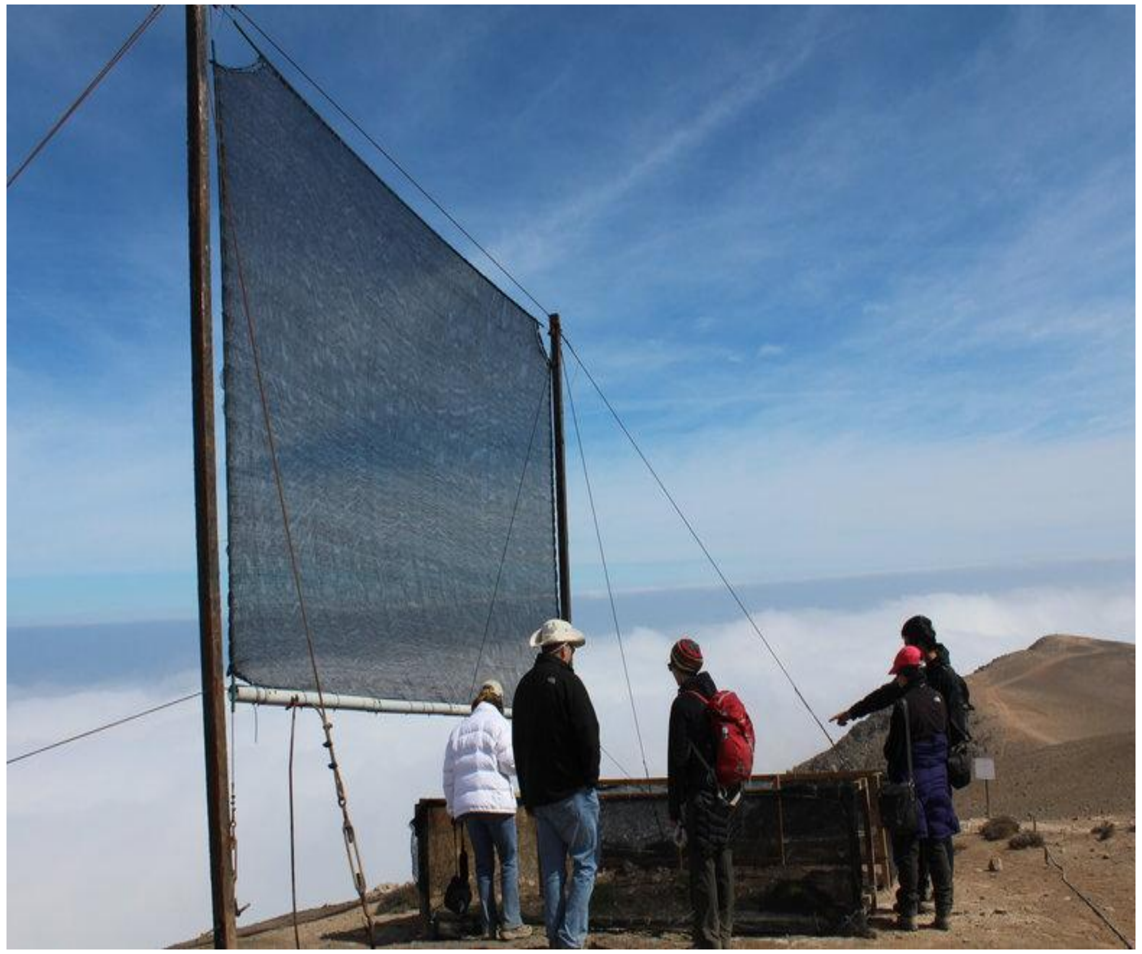
I	II	III
copying form and shape	copying a process	mimicking at an ecosystem's level

The exploration will focus on the first two types of biomimicry, so not only copying the form and shape but also copying the process.

WATER MANAGE

I would like to find a biomimicry concept that addresses the rain protection and water collection & storage, enabling creation of sheltered space for humans and other species need.

DROPwise CONDENSATION

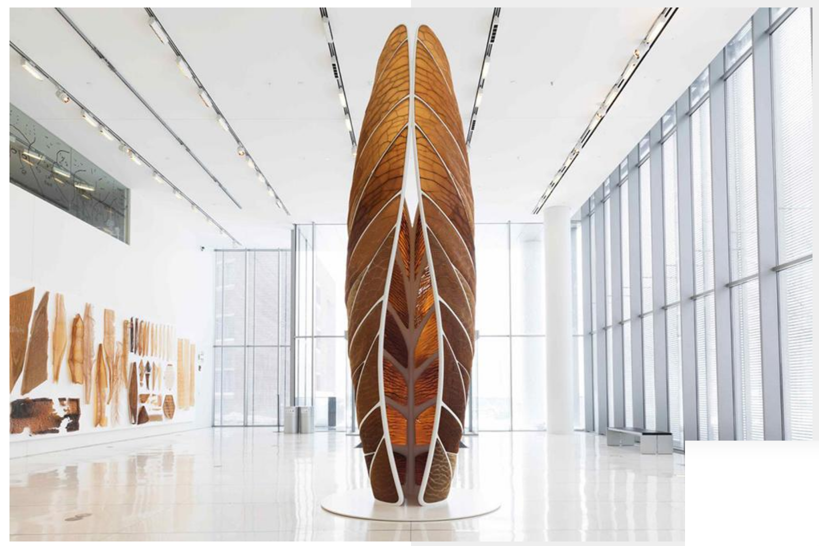


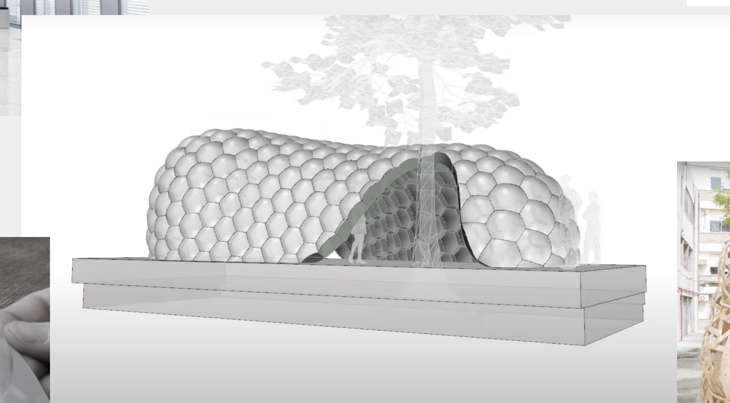
Soon, the focus of the project expanded toward dropwise condensation, as it seemed to be more challenging and interesting than just rainwater collection.

Dropwise condensation is a way to draw water directly from air without needing to wait for rain. It happens when moist air meets a dry or cold surface and collects into small droplets which drip off when they become large enough.

In their most basic form, these nets are a woven fabric mesh strung up between two poles: as the fog passes through the net, it leaves behind tiny droplets of condensation, which drip down into a greater amount of water that can be collected.

REFERENCE PROJECTS



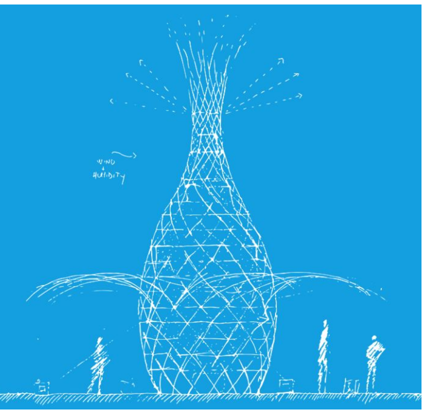


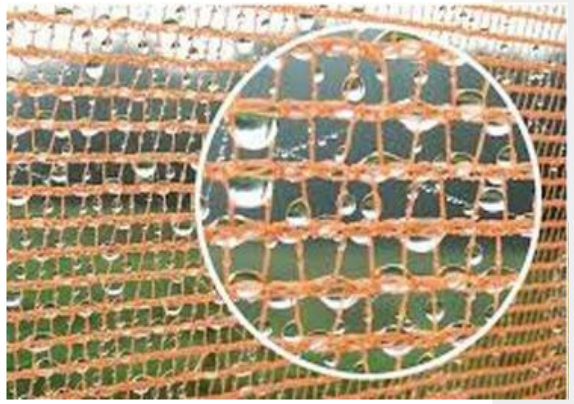
WARKA TOWER by architecture and visions

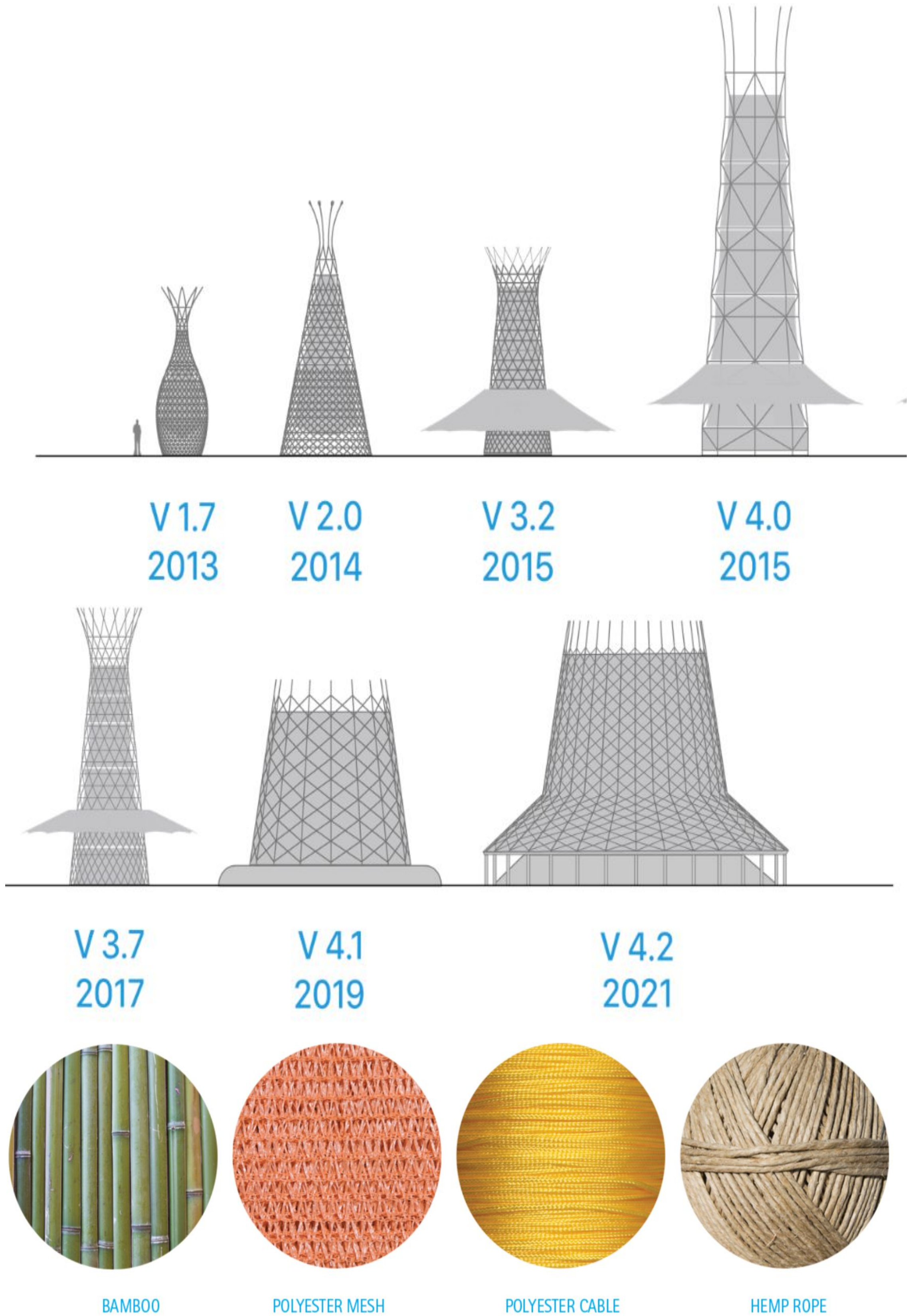
The tower was designed in Kenia to collects the water from the air based on local conditions - rain, fog, dew, forming the droplets of liquid water that go down into a container that's on the bottom. Warka Tower is designed to harvest water from the atmosphere (rain, fog, dew) providing an alternative water source for rural populations that face challenges accessing drinkable water.

BIOMIMICRY INSPIRATION:

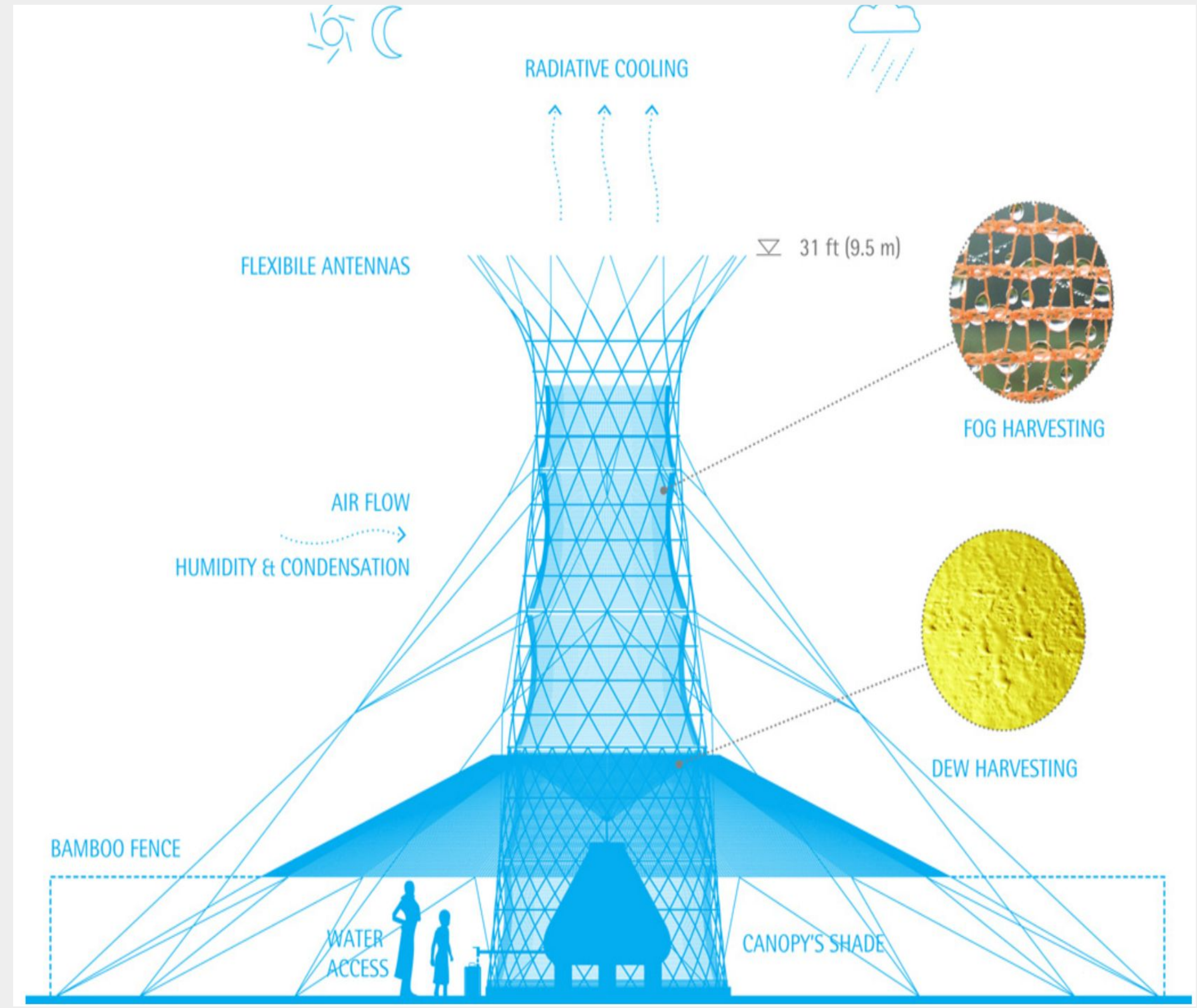
Darkling beetles live in the Namib Desert, one of the driest habitats in the world. They are able to collect the water directly from air, from dew and ocean fog. The beetle has special tips and bumps on its wing scales that help it to collect water. Water in the air condenses on the tips to form water droplets, which then flow off the bumps and into the beetle's mouth.







Could microsilk mesh be provided instead of poliester?



MICROSILK

Microsilk can be produced with less environmental impact than traditional textile manufacturing, with the potential to biodegrade at the end of its useful life.

At Bolt Threads, we believe that living in an increasingly resource-constrained world means we have a responsibility to find more sustainable ways of creating materials. Microsilk is protein-based and therefore has the potential to biodegrade, unlike polyester and other synthetic fibers that are contributing to microfiber pollution.

PRODUCTION PROCESS

We study silk proteins spun by spiders to determine what gives them their incredible properties.

We develop proteins inspired by these natural silks by using bioengineering to put genes into yeast.

We produce the protein in large quantities through fermentation, using yeast, sugar, and water.

We isolate and purify the silk protein, then spin it into fibers, similar to those like rayon and acrylic.

We knit these fibers into fabrics and garments.

BOLT THREADS

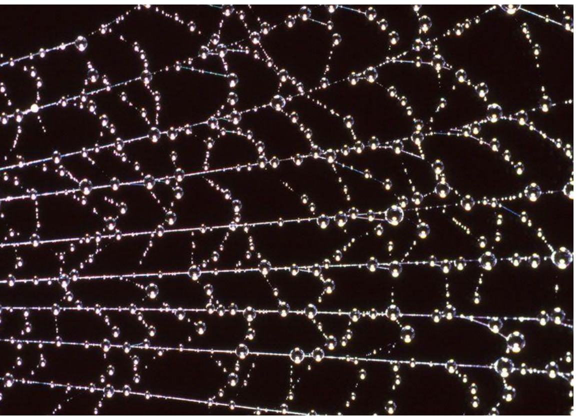
ANIMALS & PLANTS

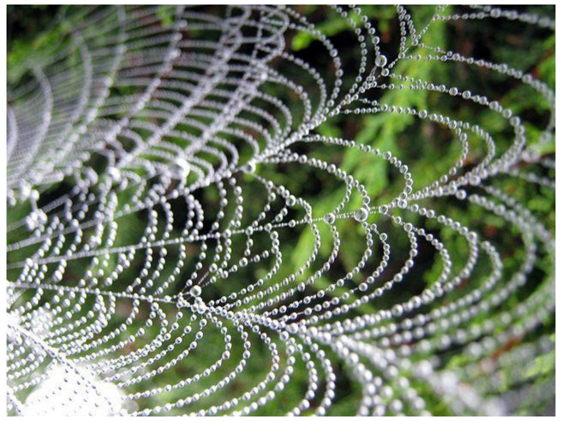
Many problems existing in nature has already been solved by organisms that have had to adapt to environments in which water is scarce, intermittent or excessive. Some species have evolved ways to harvest water from the air in deserts, store water for periods of scarcity or thrive in locations with as much as 11m of rainfall per annum. I created a collection of animals and plants to better understand how the process of water and dew collection appears.

SPIDERS

Small and often out of sight, spiders may seem little more than a decorative footnote to nature. In reality, they're some of nature's most remarkable engineers. To create the webs they use to trap meals, they turn a liquid into a fiber that's far thinner than a human hair and five times stronger than steel. Most surprisingly, these fibers are produced instantaneously, from the spiders' own bodies, using only raw materials they get from the insects and other prey they catch.

SPIDER'S WEB



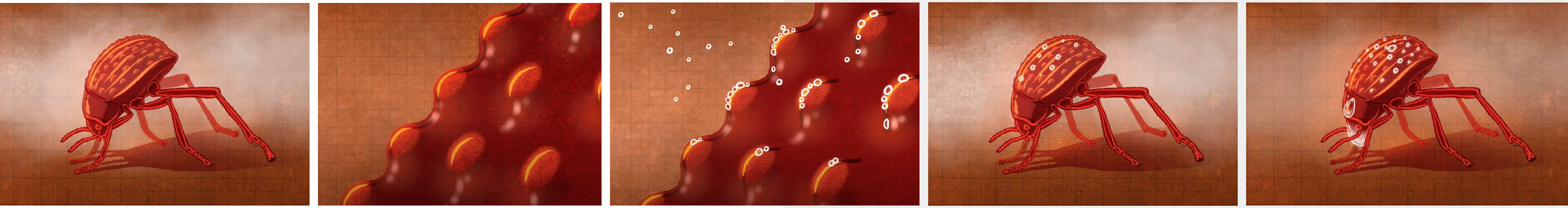


Water vapor condenses on all parts of the web, but it doesn't stay equally spread throughout. Instead, once it condenses the water quickly starts to move, migrating from the thin threads towards the tangles. This happens because the tangled parts of the web have more area for the water to stick to, which ends up pulling the water from the threads, which are thinner and have less area for water to stick to. The curved shape of the tangles also helps channel water. The result is that water collects and gets stored in the tangles, creating larger and larger water drops. This movement of the water also creates new, exposed, relatively dry silk along the threads again, to which more water vapor from the air collects, in a continuous process.

DARKLING BEETLE

Darkling beetles (family Tenebrionidae) of the Namib Desert, located on the southwest coast of Africa, live in one of the driest habitats in the world. But some species of Darkling beetle can get the water they need from dew and ocean fog, using their very own body surfaces.

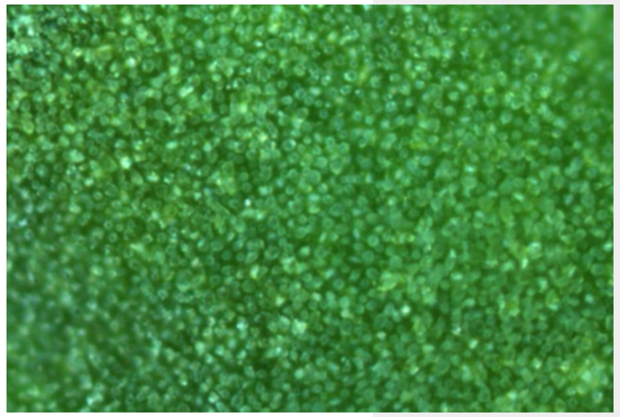
His back is covered with hydrophilic bumps and hydrophobic slopes. This structure allows droplets to stick to the surface and form larger drops. Due to gravity, the drops roll down to the beetle's mouth.

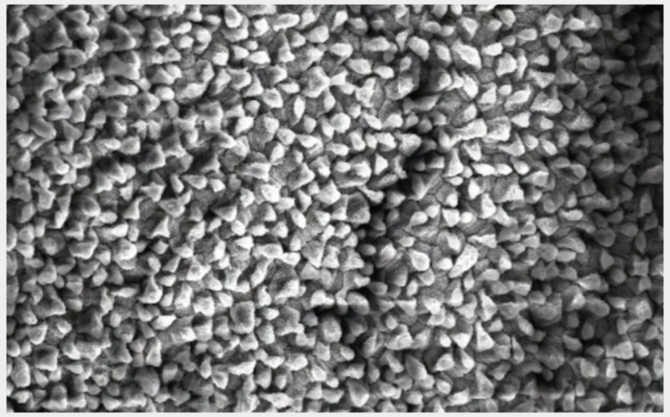


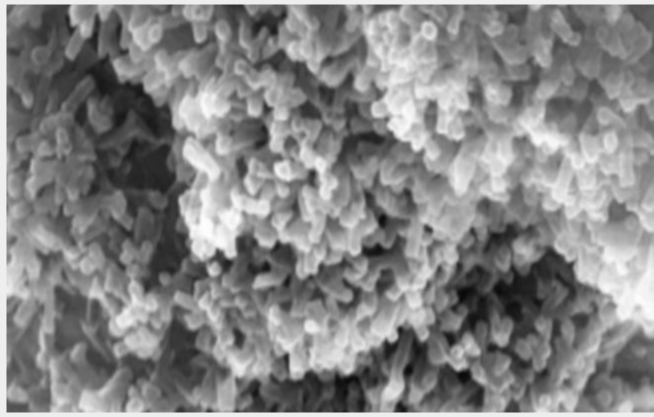
BBC world service

LOTUS LEAVES

Lotus leaves, for example, exhibit extensive folding (i.e., papillose epidermal cells) and epicuticular wax crystals jutting out from the plant's surface, resulting in a roughened microscale surface. As water and air adhere less well than water and solids, roughened surfaces tend to reduce adhesive force on water droplets, as trapped air in the interstitial spaces of the roughened surface result in a reduced liquid-to-solid contact area. This allows the self-attraction of the polar molecule of water to express more fully, causing it to form spheres.







OTHER PLANTS AND ANIMALS

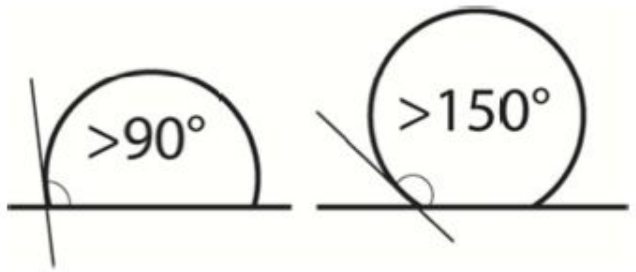
WHAT DOES INFLUENCE DEW COLLECTION?

1. HYDROPHOBIC surface, mixed with hydrophilic

2. ROUGH/ BUMPY TEXTURE

3. SPECIFIC NANO-STRUCTURE

HYDROPHOBICITY



The simplest explanation of hydrophobicity is a surface having a static water contact angle higher than 90˚, while a superhydrophobic surface is supposed to exhibit a contact angle higher than 150˚

Nano/micro roughness causes an increase or decrease in the the contact angle depending on the nature of solid substrates. Trapped air causes an increase in the contact angle for hydrophobic surfaces.

Roughness increases the surface area , hydrophobic surface trapped the air , and increase in roughness leads to higher hydrophobicity but hydrophil surface with large surface or higher roughness leads to increase polar interaction with water droplet and decrease water contact angle.

Rough sphere with 1mm bumps can capture fog 2.5 times better than smooth sphere.

DEW CATCHING PANELS

Warka Tower inspired me to make a one step further and design a dew catching panels inspired by the schelleton of the beatle. Increase in the surface, from polyester mesh to a solid panel would increase the water collection.

To find a right material that could imitate the beetle's schelleton and be able to collect water vapour I had to research more to understand how the condensation and dew collection work.

CONDENSATION

CONDENSATION of water appears when vapor changes to a liquid. Condensation may occur either when the air is cooled to its dew point or it becomes so saturated with water vapor that the water condenses.

In this process, the condensing surface loses heat to the environment, causing its temperature to be lower than the surrounding atmospheric air. This cooling process usually happens on cold nights, with high humidity, wind with speeds below 4.4 m/s, and clear sky (Beysens 2016). Thus, when finding a surface with a temperature at or below the dew point temperature, water vapor condenses. After condensation, water droplets slide by gravity and can then be stored (Tomaszkiewicz *et al.* 2015).

DEW

CONDENSATION of water appears when vapor changes to a liquid. Condensation may occur either when the air is cooled to its dew point or it becomes so saturated with water vapor that the water condenses.

DEW POINT - is the temperature at which the condensation happens.

An intense heat radiation from the surfaces during night causes decrease of its' temperature. If the temperature of the bodies drops below the dew point, water vapor will condense on them, forming dew drops.

CONCLUSIONS:

As the formation of the dew is related to the temperature of the surface on which it appears, the surface has to have the ability of high heat transfer; thus have ideal relation between thermal conductivity and the thickness of the material.

THERMAL CONDUCTIVITY

PLASTIC(PE)

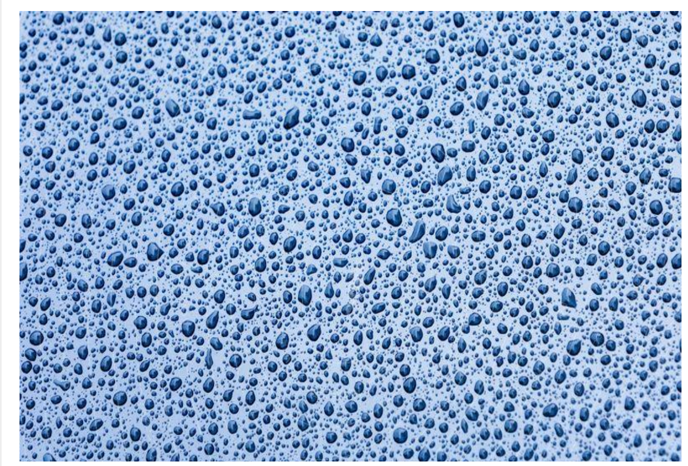
0.5 W/mK

STEEL

>/45 W/mK

GLASS

0.8 W/mK



THERMAL CONDUCTIVITY

GRASS

0.2-0.5 W/mK

CHITIN
0.73-0.82 W/mK

RECYCLED PLASTIC FROM OCEAN WASTE

The comparison of thermal factors of man-made materials that provide dew condensation, led me to the conclusion that either plastic or glass are the closest ones to mimic the beetle's schelleton when liquid condensation.

I thought that such panels could be created from the recycled plastic from the ocean waste, as the plastic works better in very thin sections than glass, which is very brittle. (thinness of the material indicates radiative cooling)

BIOPLASTIC

As I wanted to experiment with the shape of the panels, rather then create a finished final product, I chose bioplastic as a prototype-making material. Bioplastic is a biobased polymer derived from a biomass and it may or may not be biodegradable and soluble in water.

PRODUCTS USED:
WATER

GELATIN

GLYCEROL - less glycerol creates more brittle but harder material, more glycerol will make a flexible and softer one

VINEGAR

STARCH

different hardness may occur depending on the quantities of above ingredients

STARCH based BIOPLASTIC

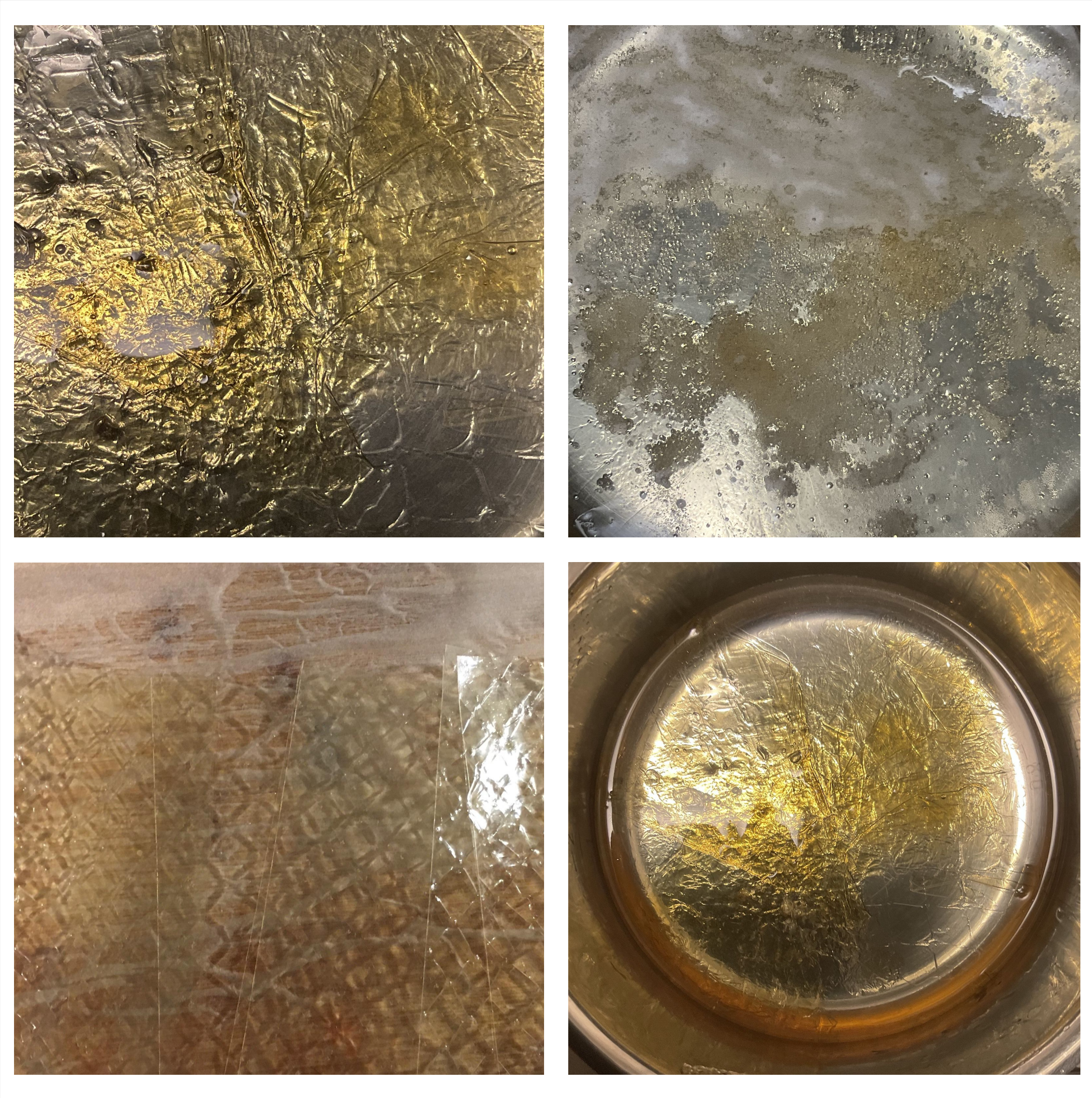
WATER 240ML STARCH 60ML   GLYCEROL 20ML VINEGAR 20ML

The mixture was very dense and viscous, and couldn't be poured easily into the mold. All attempts ended up with cracking the material during the drying process. Probably the mass was heated for too short period of time and too little water evaporated before drying.

GELATINE based BIOPLASTIC

WATER 120ML GELATINE 19G GLYCEROL 5ML

The mixture was very thin and easily poured into the mold. It was very easy to work with as it didn't cracl during the drying process.

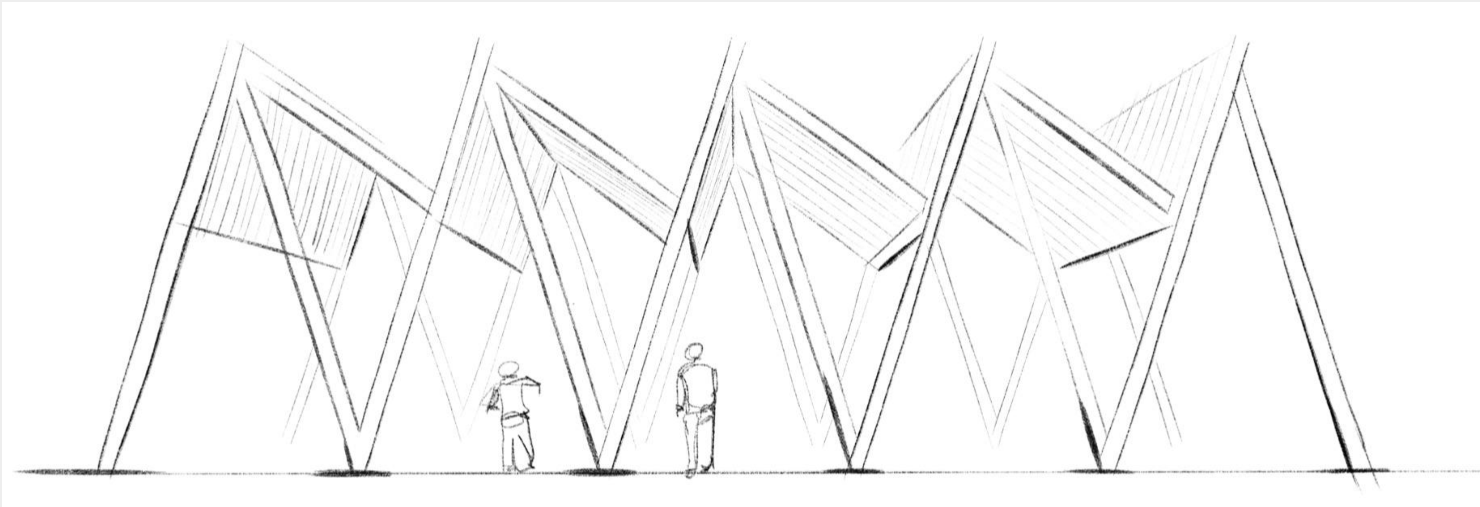


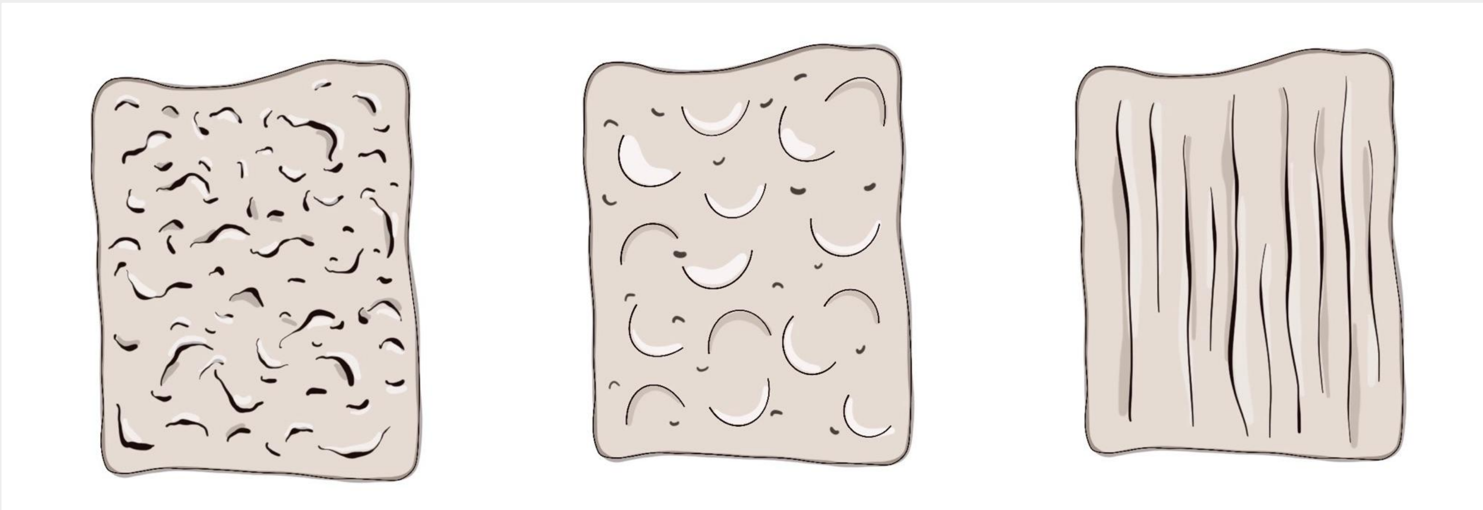
GELATINE based BIOPLASTIC

WATER 120ML GELATINE 19G   GLYCEROL 5ML

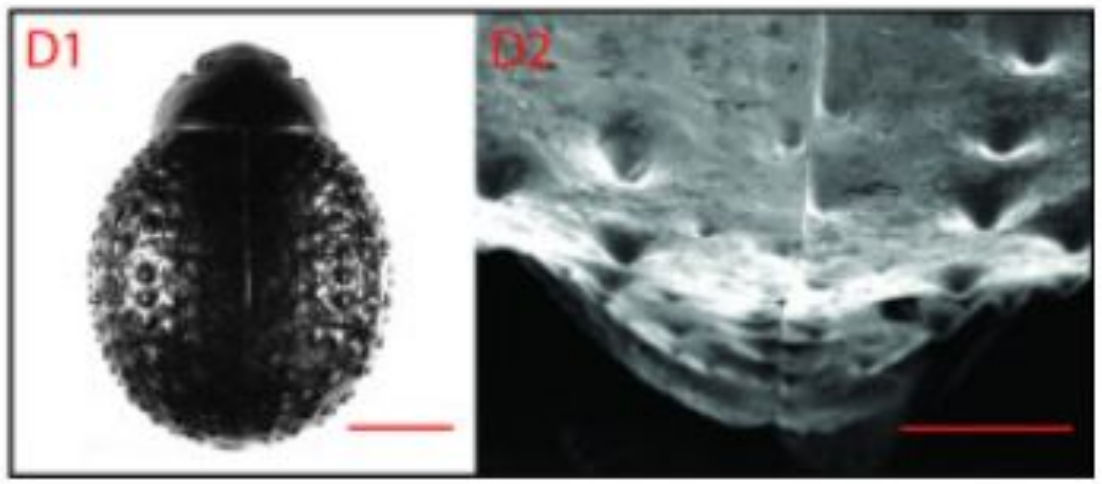
After 12 hours of drying, the material was still half-dried and very elastic. It hardened after 48-72 hours.

DEW CATCHING PANELS



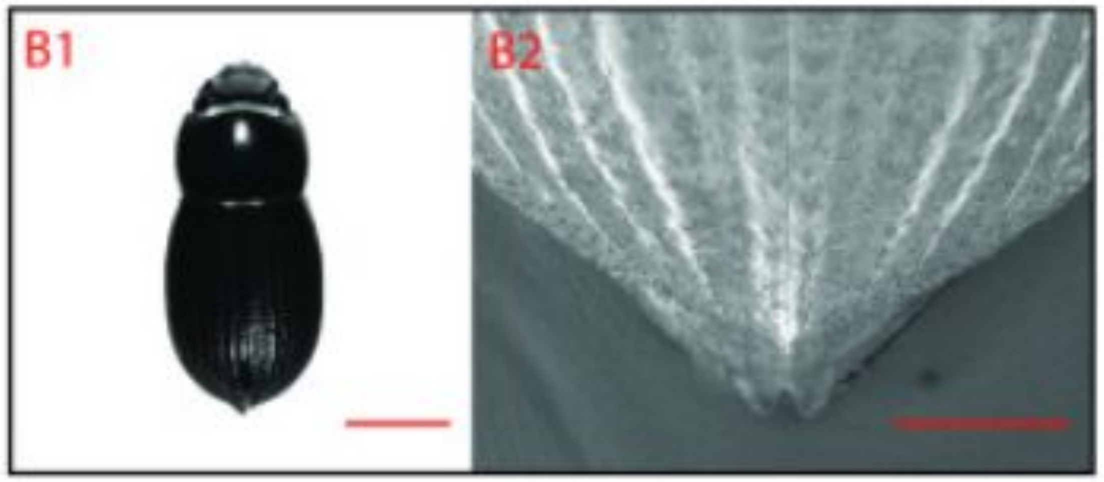


PANELS prototypes inspired by beetle's shelleton



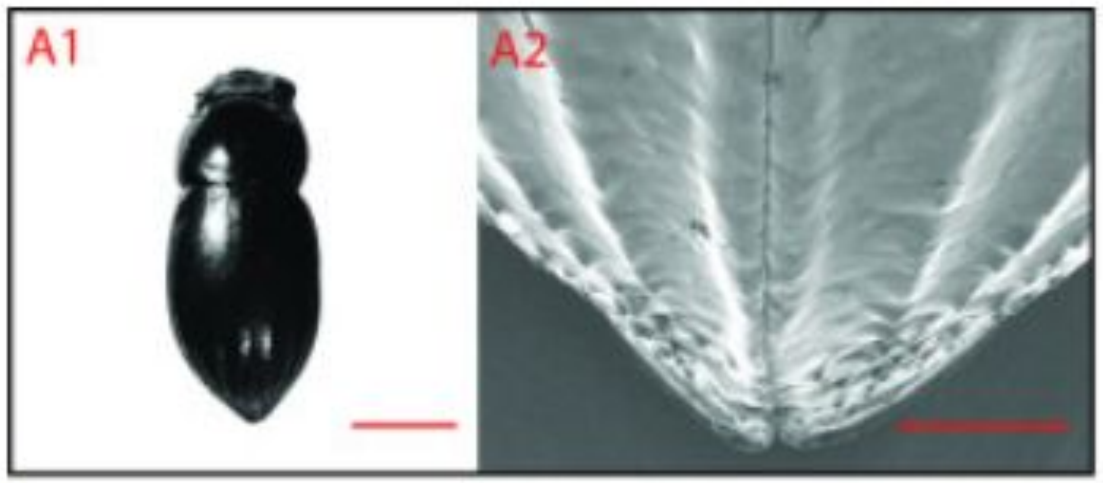
material: water + gelatine + glycerol

PANELS prototypes inspired by beetle's shelleton



material: water + gelatine + glycerol

PANELS prototypes inspired by
beetle's shelleton



material: water + gelatine + glycerol

MODELING WITH RICE PAPER

I tried to make panels prototyped with rice-paper but it didn't work well, the rice paper was not handy in use. Too sticky texture after soaking in water, hard to operate. After drying was very brittle and it break when taking out from the mold.

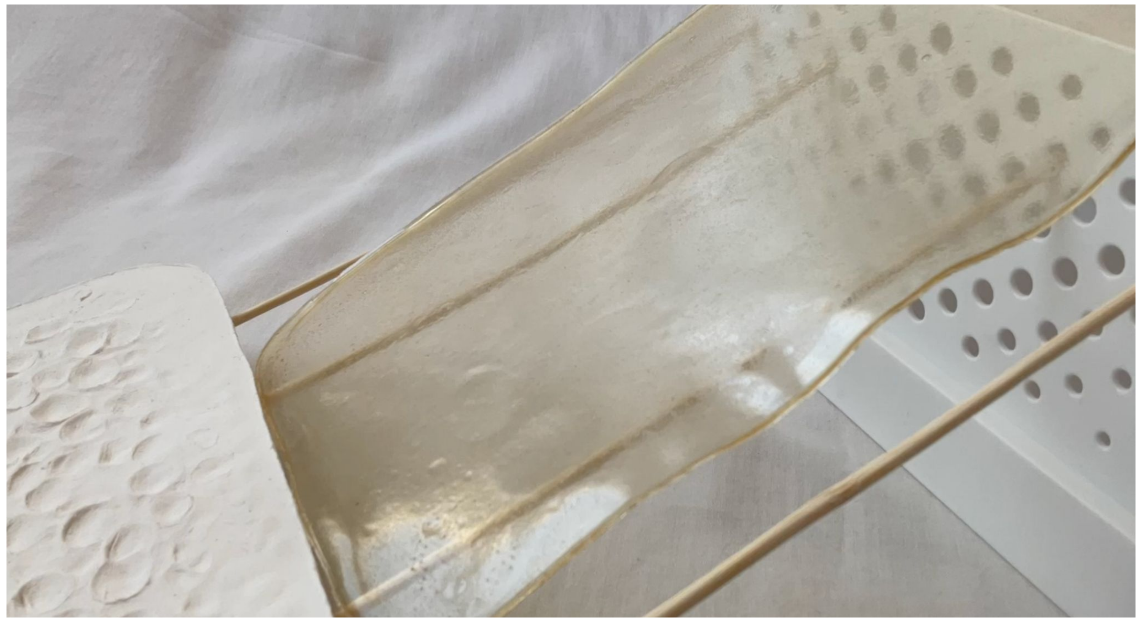
I tried to dissolve it with glicerol to make it more flexible. Then it started to look more like a bioplastic I made with starch, but it cracked as well when drying.

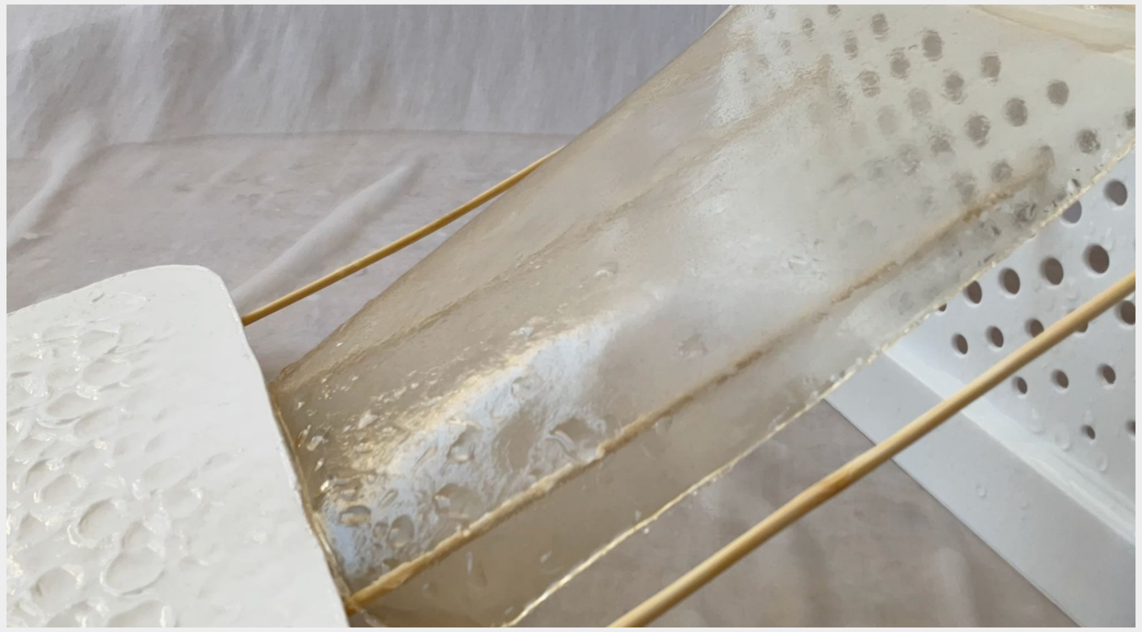
FROM DESIGN TO EXPERIMENTS

The project changed its manner in a way, as I derived from the design process and started to work more with the bio-plastic material itself. I decided to leave the design process apart and continue it in a similar manner next semester, when designing sheltered space for outdoor schooling. From now I made a few experiments to see how the bio-plastic will react with a contact with water.

SPRAYING with COLD WATER

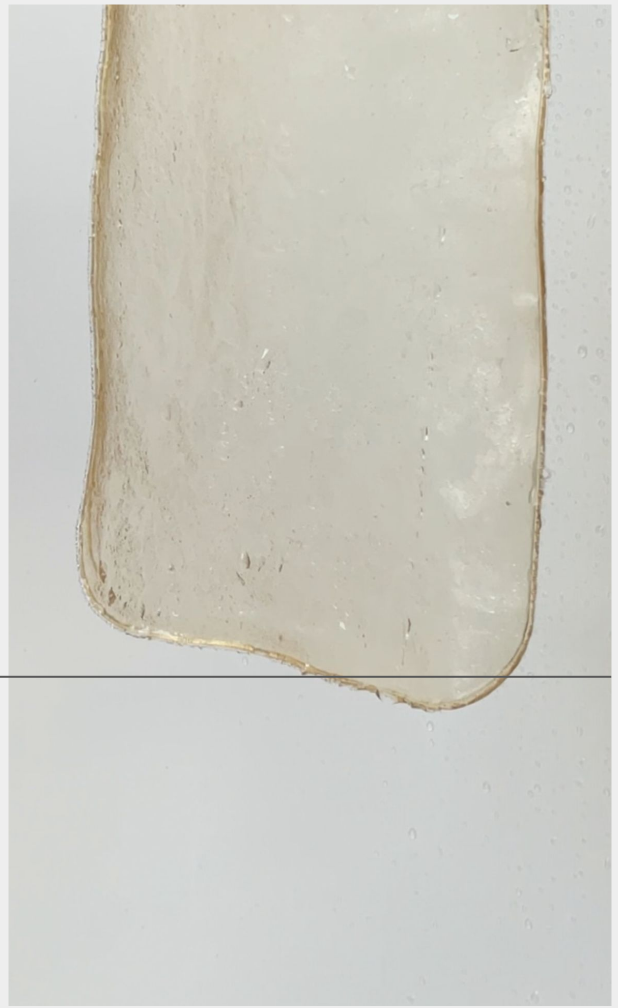
I decided to spray the material with cold water (~10-15°C) for less than 5 min. to imitate the rain and see how dried material will react with a contact with water. It lost the stiffness and become elastic again. It bent where it was not supported by the sticks, then it dried up in a new form.





SPRAYING with HOT WATER

Next sample of the material I sprayed with hot water (~60˚C) to see if there will be any changes comparing to the cold one. As I hanged the material, due to hot temperature it became elastic as well, and the length of the material expanded.



SOAKING in HOT WATER

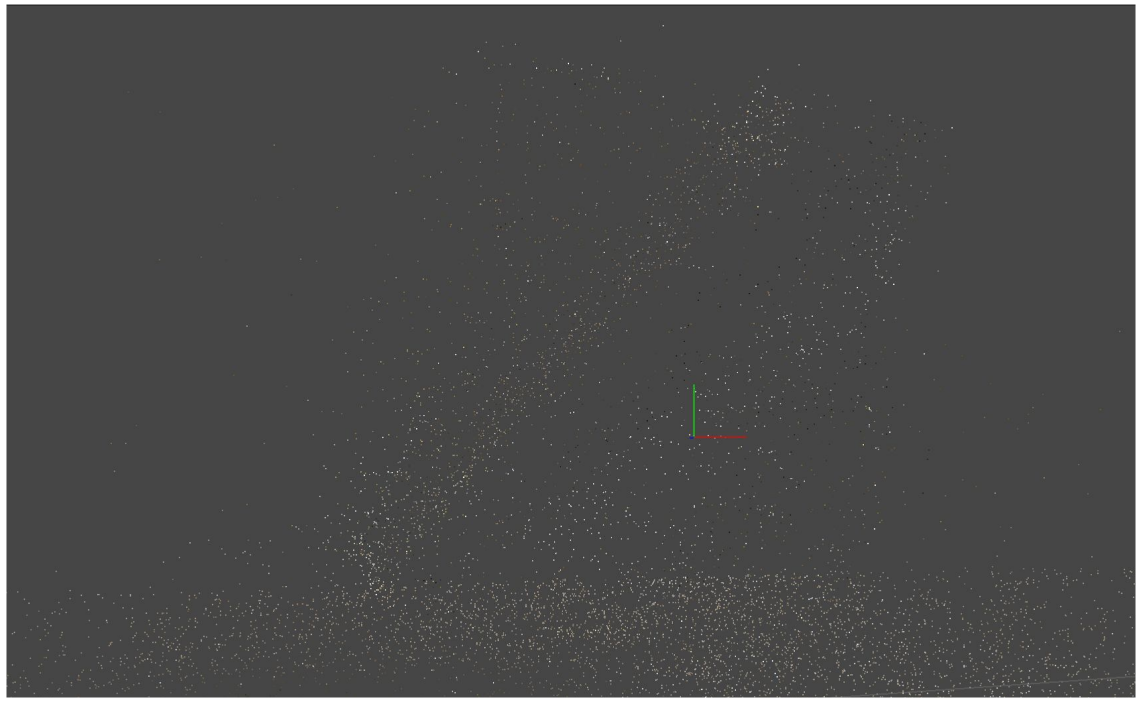
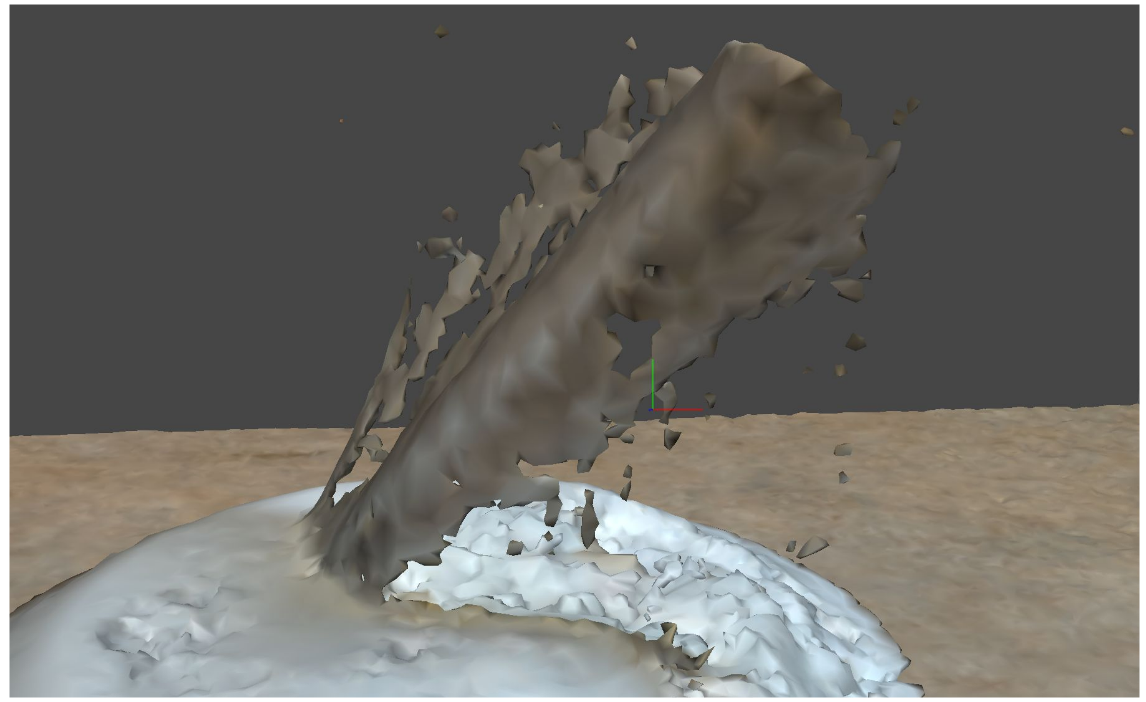
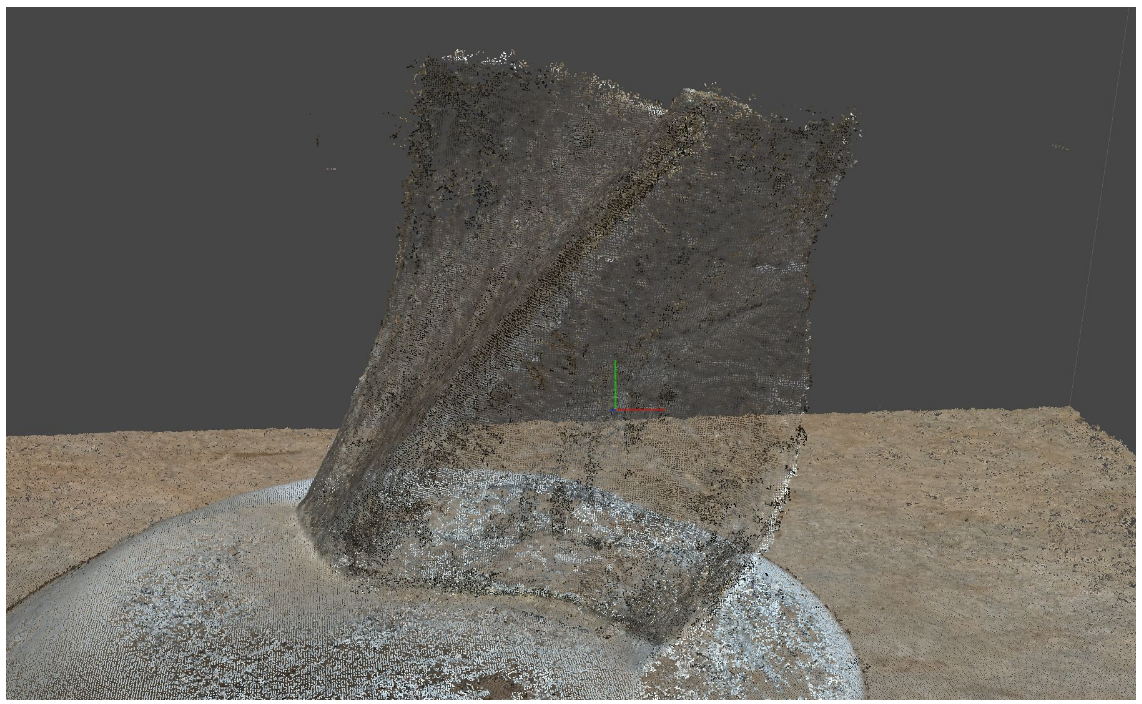
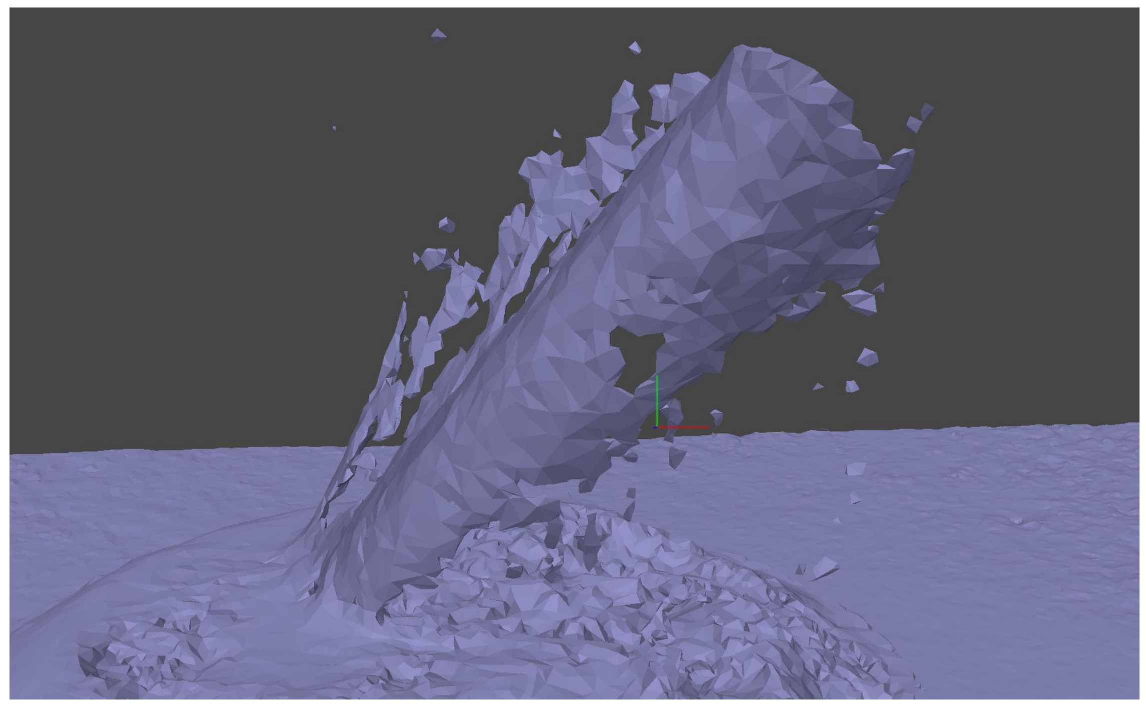
For another experiment I decided to dissolve the material entirely and soak it in a pot of hot water. The following pictures present the material was changing over time.

PHOTOGRAMMETRY

Photogrammetry of a semi-transparent object didn't work properly. Only 40% of the pictures were aligned.

PHOTOGRAMMETRY

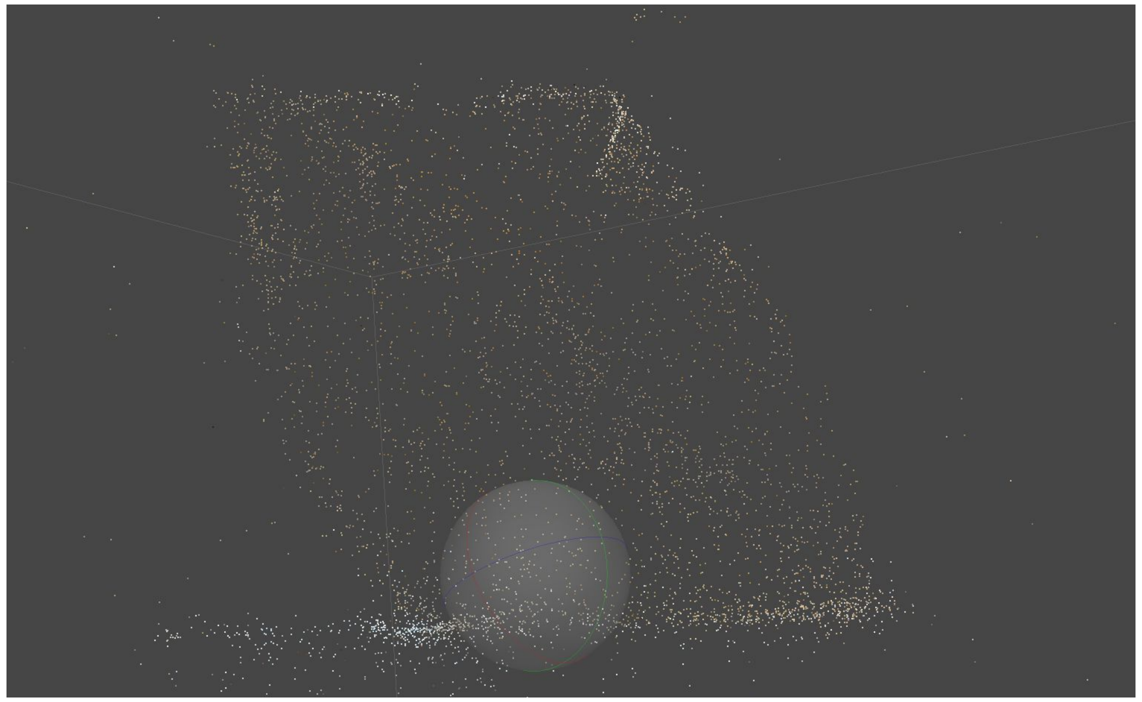
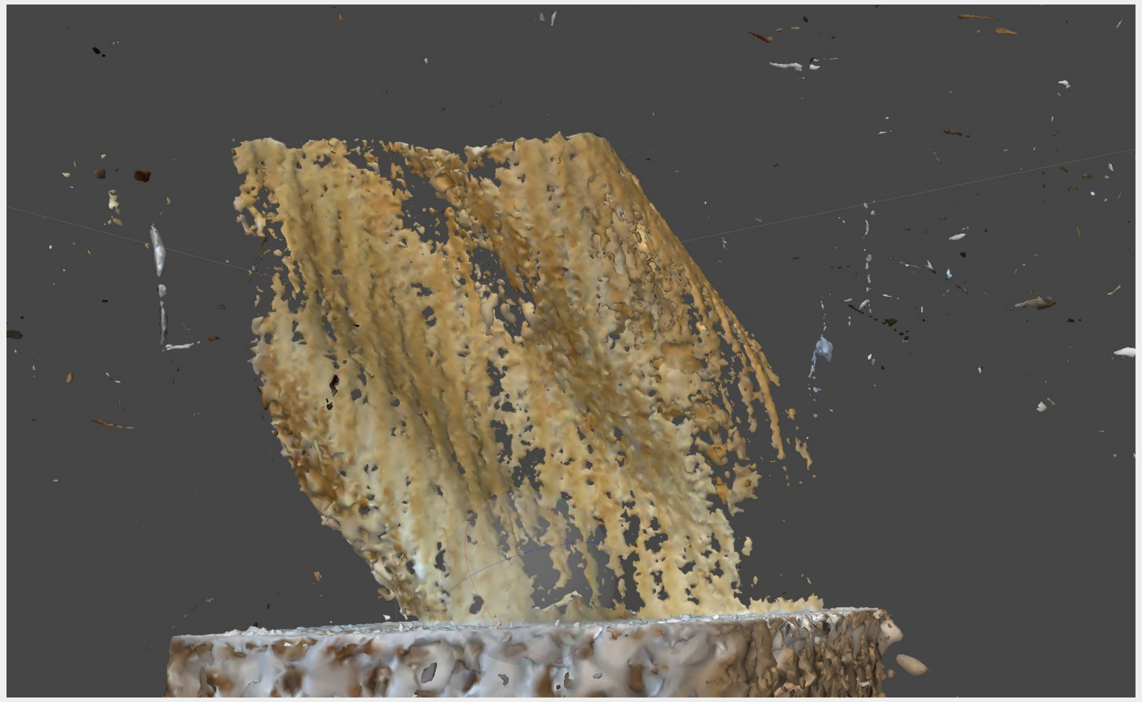
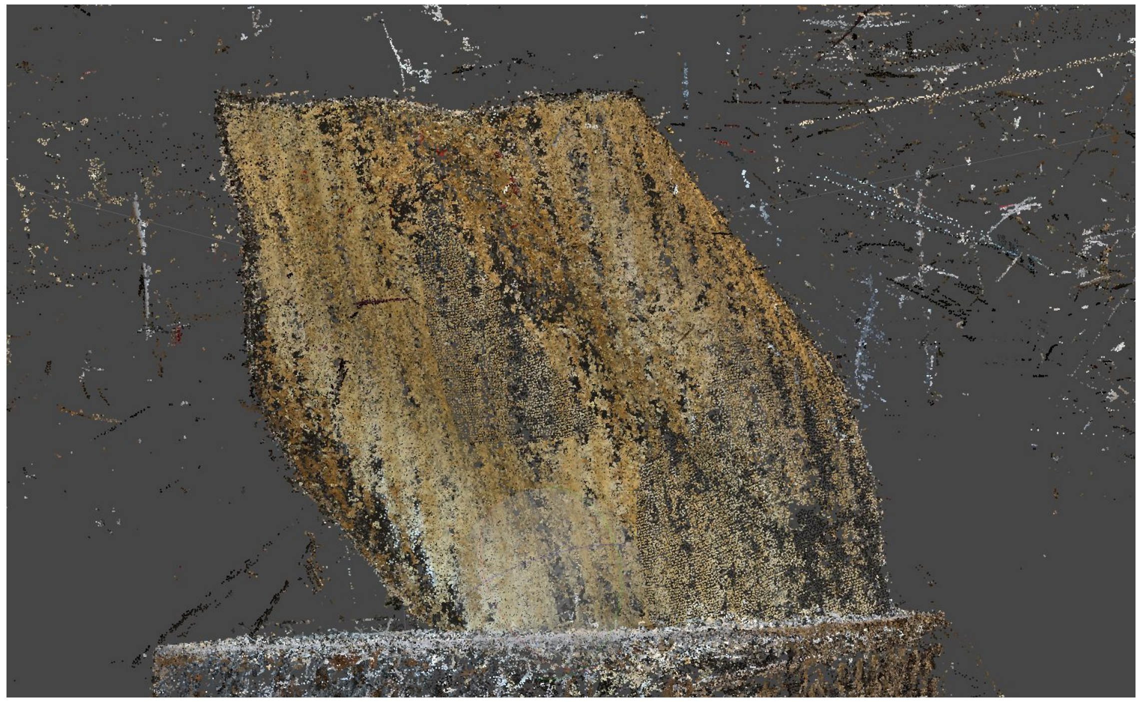
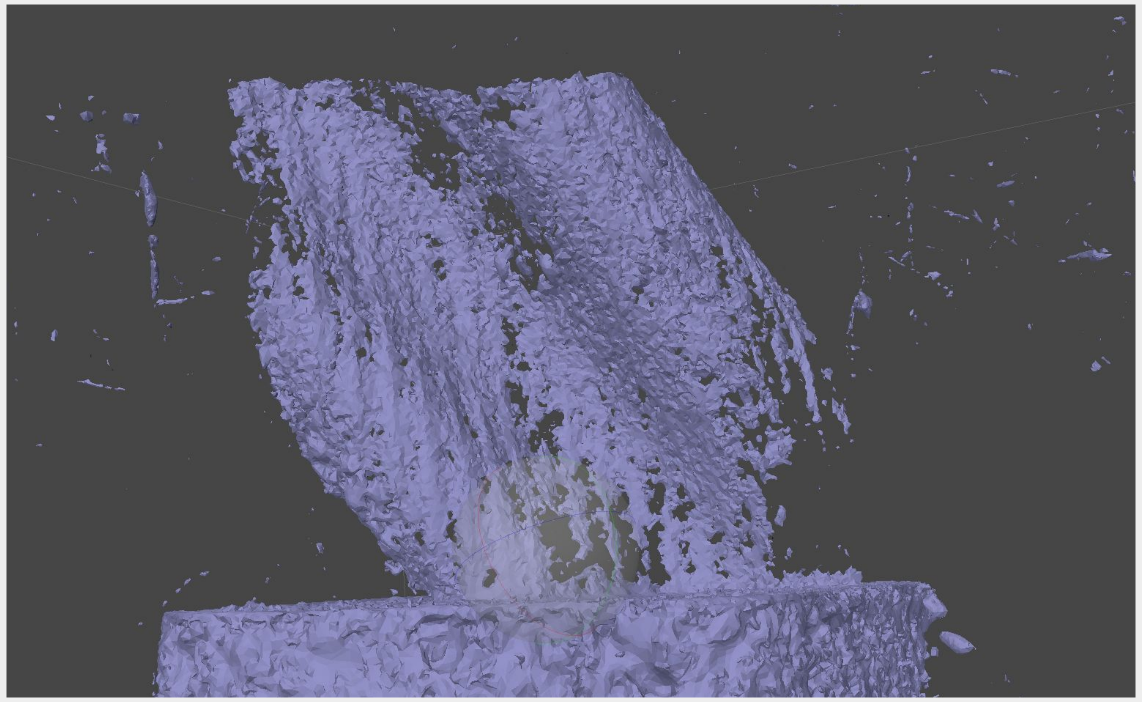
Adding aluminium foil on one side of the surfaces helped with aligning the pictures, but the pointcloud wasn't perfect.

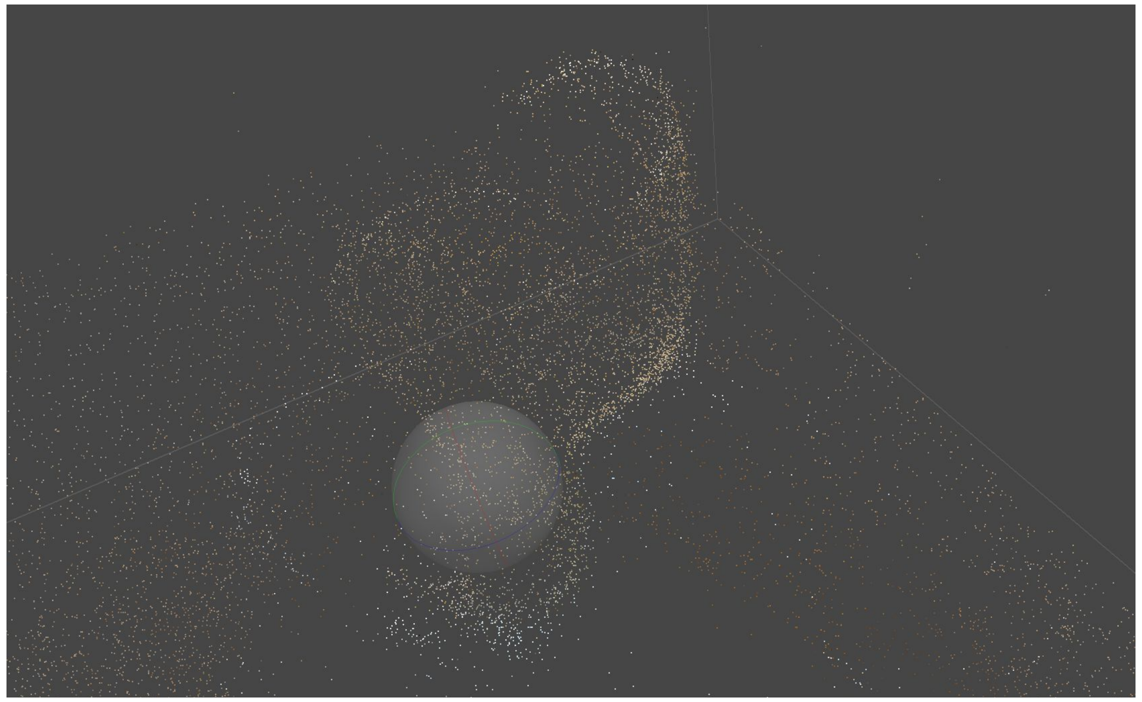





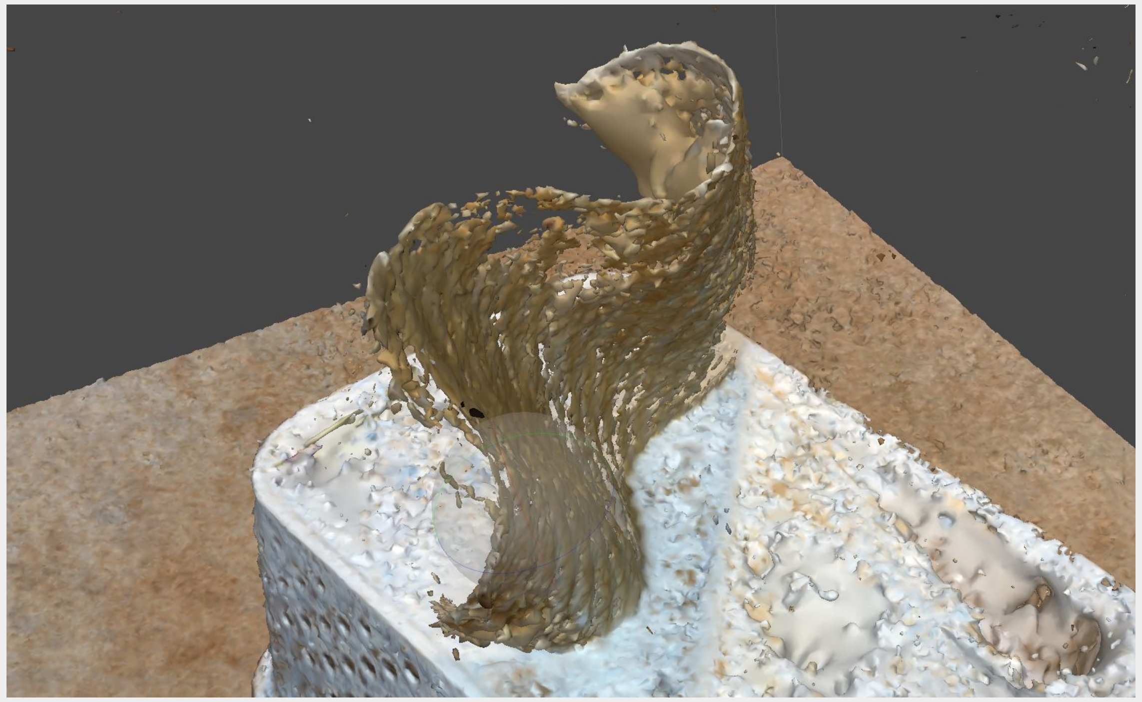
PHOTOGRAMMETRY

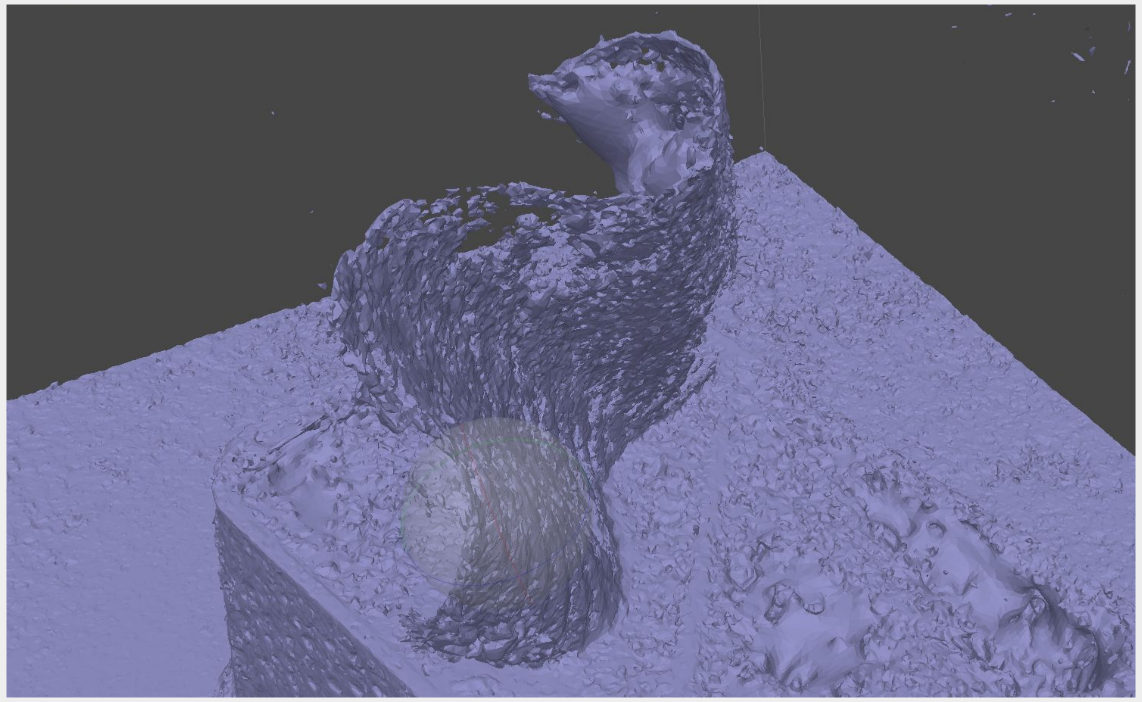
I decided to paint one of the surfaces of the model, to make it more uniform, as the mesh created in metashape was't fully built.

The result was much better, but the mesh still wasn't ideal.

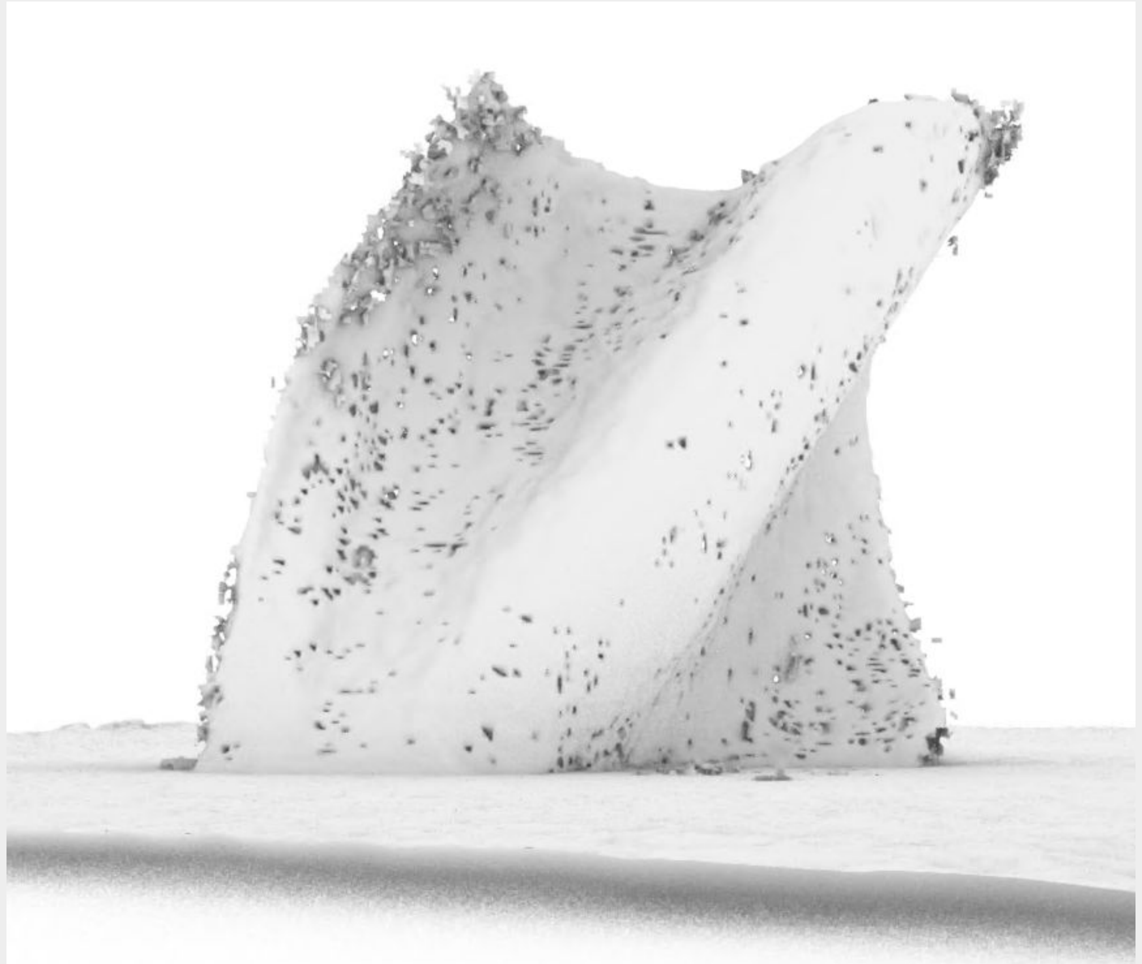






RHINO

I decided to export the dense point cloud from Metashape directly to Rhino to build the mesh directly there. The result was most satisfying.



A MOLD FOR MYCELIUM COMPOSITES

Experimenting with bioplastic let me develop a tool for designing a mold for mycelium composites, that I will use during my MT. Bio plastic made from gelatine and glycerol is very handy in creating organic smooth shapes, once it's not fully dried. It gives a better understanding of created forms in reality. If it dries, it can be reused multiple times; either by soaking it in water, which allows it to get back to elastic form, enabling to be reformed to another shape, or melting it to a liquid form and casting again into a new composites form.

PREPARING THE MOLD FOR COMPOSITES:

1. designing the shape of the composite with half-dired bioplastic

2. transforming the dried shape into 3d object in Rhino using photogrammetry.

3. cutting the mold in wood using the cnc machine.

4. creating the final plastic mold for mycelium composite using vacume machine.

REFLECTION

When I chose biomimicry as a discourse for my project, I wanted to research how we can learn from nature and translate adaptation in biology into architecture. I soon realized that I miss biological knowledge, to be able to come up with a relevant biomimicry concept, as I wanted to create something that imitates not only the shape but process as well.

It became difficult to find a satisfactory reference project, as there are a few ones since the biomimicry approach is often superficially interpreted. Some people do not take the time to look deeply into the concept of biomimicry to truly understand it and lack the knowledge to understand how processes occur in nature.

As I started to read about rain, dew collection, and condensation, it became an explorative process of better understanding nature and processes that occurs. I struggled a bit in the beginning and was scared that I won't be able to create anything meaningful based on biomimicry.

After the second critique, I decided to leave the design process apart and continue it similarly next semester during MT. I think that I dedicated most of my energy to the biomimicry concept research and understanding nature, and was more excited to experiment further with the bioplastic material itself rather than designing a final product.

The experiments I conducted in the last module helped me better understand the bioplastic material I was working with. Quite by accident, I developed a method that I will use during my MT, as gelatine bioplastic turned out to be a perfect material for creating organic-shaped prototypes.

Regarding the dew catching panels itself, I could elaborate more on the method of joining them together and providing big scale facades, but as it turned out more into exploration with the material, I decided to leave the design process apart and continue it in a similar manner next semester