

Ecological Futures: Prototyping a SENSORIAL SPONGE as a CO2 reducing art object

Keywords: bioart, open culture bioexperimentation, biotechnology, human/non-human collaboration, symbiosis between organisms, tools and technologies for biological experimentation

Abstract

The present proposal fits within my broader socio-artistic agenda. I want to investigate in how far a living bacterial sculpture can function as a CO2 reducing and oxygen generating object for use inside the home. The development of this object will be based upon my previous work with cyanobacteria, I will implement the knowledge that I gathered during my biotech-project 'Sensorial Skin' (development of a pollution sensor).

I believe the usage of cyanobacteria, also called blue-green algae, are a promising path to achieve these objectives. Photosynthetic cyanobacteria clean the air. They perform *photosynthesis* in a similar way plants do. They contain light-harvesting pigments, absorb carbon dioxide and release oxygen. For the shape and texture of the exoskeleton on which these air-cleaning cyanobacteria will grow, I will draw my inspiration from nature: I will study the shapes, pores and pump mechanisms of *Porifera*, the family of Sea Sponges.

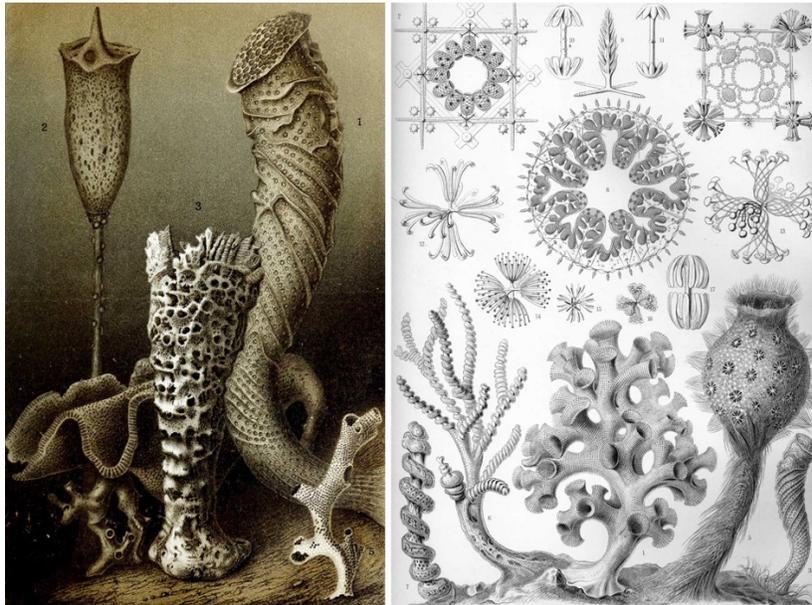


Fig. 1: Various *Porifera*, Hexactinellid sponges (Glass Sponge), an animal living at a depth of \pm 500 metres.

Fig. 2: Ernst Haeckel - *Kunstformen der Natur*: Hexactinellae (*Porifera*)

Concept

The concept for my CO2 reducing object is based upon a combination of properties of 2 natural organisms, namely 1) the flow mechanism and aesthetic forms of a Sea Sponge and 2) the air-cleaning qualities of Cyanobacteria. A Sponge (phylum *Porifera*) is a multicellular organism that has a body full of pores and channels allowing water (or air) to circulate through them. The sponge takes in water at the bottom and ejects it at the top. Cyanobacteria perform photosynthesis where they take in CO2 (with water and sunlight) and return clean oxygen. Setting up a cyanobacterial culture in the body (form) of a Sea Sponge sounds like a perfect fit. I am especially interested in the match between the 2 different

organisms. Whilst I am impressed by the Sea Sponge for its aesthetic forms and ingenious pumping mechanisms, I am informed via former research about the benefits of cyanobacteria with respect to CO₂ reduction in the air.

I will build upon the research I started in the art-science lab of Prof. Raoul Frese (Hybrid Forms Lab, Free University of Amsterdam), where I recently did a STARTS residency. I will continue my study of the versatile possibilities of algae and cyanobacteria to develop a biomimetic and futuristic-looking Sensorial Sponge, a living art object that is at the same time a natural air cleaner.

Researching all these possibilities, and developing the general concept of an interactive object work in a practical sense, requires intimate interaction with a residency place providing practical support in form of bio/fablab facilities so that biotechnological experimentation and production become feasible. For me, as an artist, the aesthetical dimension of the project is very important. The forms created by organisms such as bacteria and sea animals have undeniably an astounding beauty which I want to make visible, as a way to create awe and hence appreciation and respect for Nature.

My goal is to develop prototypes of the Sensorial Sponge object in the TRAKK FabLab. I have experience working together with artists and designers at the Green fablab of the architecture institute (IAAC) in Barcelona, where I prototyped my Intelligent Beehives enhanced with DIY technology and where I did experiments on bee monitoring in the Collserola mountains. At TRAKK in Namur, I intend to develop Sensorial Sponge prototypes starting from 3D drawings. I will let my cyanobacteria grow on 3d printed and CNC-milled exoskeletons on forms derived from Sea Sponge skeletons. I also want to mimic the flow mechanism of this sea animal, and thus enhance my prototypes with DIY and off-the-shelf electronics (e.g. peristaltic pumps and airpumps) to turn my models into working objects.

Background

I can draw on experience gained during my project Sensorial Skin and the artwork 'L'Origine du Monde' derived from it. 'Sensorial Skin' [for an Intelligent Beehive] is a bio-art project on the edge of art and science. It researches the possibility to grow a biosensor from cyanobacteria, in the form of a sensorial tissue. This Sensorial Skin can measure air pollution and visualize the pollution by changes in colour. It combines in a radical way smart materials, biomimetic forms and biotechnology.

The project is inspired by the intelligence, complexity and self-organisation of bee colonies as Super Organisms and evokes issues of sustainability and biodiversity, giving viewers an artistic experience of my ongoing research related to the disappearance of the honeybee.



Fig.3: Intelligent Guerrilla Beehive v. 01

Fig.4: 3D printed exoskeleton with a Sensorial Skin grown by *Acetobacter xylinum* bacteria, inoculated with *Lactobacillus plantarum* grown into a biofilm

To tackle the harmful treatment of honeybees, I developed a radically new beehive: The Intelligent Beehive. This mobile shelter for swarming honeybees is designed for urban environments. It supports the bee colonies in their pollination tasks, and as result indemnifies the biodiversity of their foraging fields. Its goal is a double one. The inside of this bespoke beehive offers a safe refuge tailored to the needs of a honeybee colony as if living in the wild. A co-habitation with symbiotic bacteria has a positive influence on their immune system. The outside of the hive is a biosensor that interacts with the environment. A bacterial tissue measures the pollution of the foraging fields around the beehive by changing colour when a specific threshold of fine dust is passed. The bacterial shield will thus reflect the information about the state of the environment, for example by changes in light, colour or texture, so that the cover shield becomes a 'sensorial skin'.

The 'Sensorial Sponge' project - the CO2 reducing art-object - will draw from the knowledge gathered during the research for the Sensorial Skin, though the biological mechanisms to achieve the results are different.

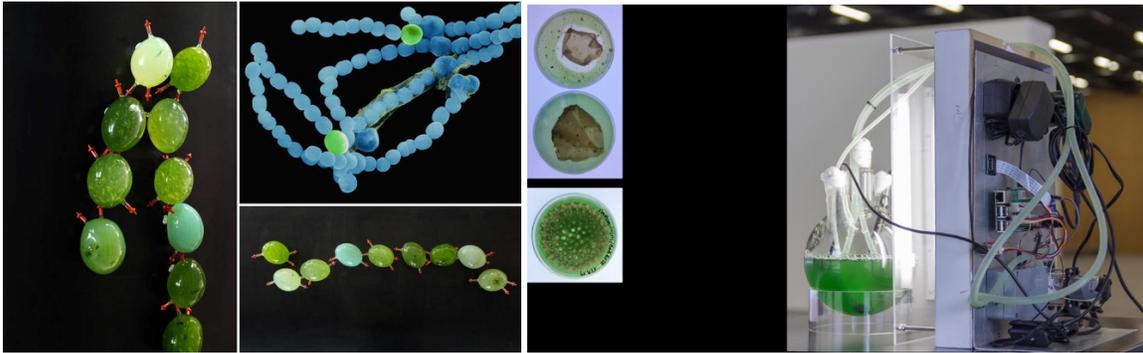


Fig.5: (left) L'Origine du Monde (bacterial chain), STARTS residencies event, le 104, Paris.
 Fig.6: (right) Cyanobacterial cultures - DIY Bioreactor 1.0 measuring pH, T° and bacterial growth, at the exhibition 'Seeing Together', KASK, School of Arts Ghent, Belgium

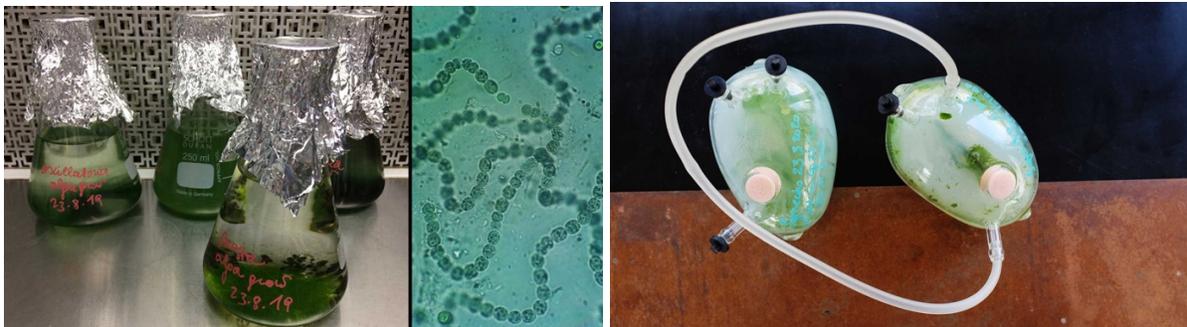


Fig.7: Today, we can enjoy an abundance of oxygen, which makes up 21 percent of the atmosphere. But when the earth formed, the ocean and atmosphere were nearly oxygen-free. That started to change when bacteria evolved the ability to harness sunlight to grow. As they carried out photosynthesis, they absorbed carbon dioxide and released oxygen.

Fig.8: Cyanobacterial cultures growing into a biofilm Sensorial Skin



Fig.9: L'Origine du Monde, bacterial chain, living installation with 35 glass cells filled with cyanobacteria processing photosynthesis. STARTS residencies days, Le Centquatre, Paris (2020, Fr)

The methodology used for the Sensorial Skin project was comprising a scientific part (the research) and an artistic part (the production and presentation). I will follow a similar methodology for the prototyping of the Sensorial Sponge object.

The information of which cyanobacteria to use best, I can easily withdraw from my Sensorial Skin project.

Resulting from an in-depth study of the aesthetical and biological mechanisms of a sponge, I will make a series of 3D drawings that will form the basis for some rapid prototyping experiments, as detailed parts of the total object. These parts will be mounted together and will be completed with the necessary electronics as peristaltic pumps and air pumps to make the object work. A further research will go into the filter materials to use best for releasing the clean oxygen-particles on top of the sponge-object. Subsequently this prototyping there will be a study of which materials to use best for the final realisation of the object. In my opinion, the final object should be created in double-sided glass, but following the research it can be possible that 3D printing with the right materials might be a better solution for the optimal functioning of the object, as the delicate pump mechanisms will be easier to realize in 3D printing than in glass blowing. CNC milling or lasering directly on rigid organic materials can be alternatives for 3D printing. In this case, I will use mathematical models based on cellular automata and reaction-diffusion systems, so that a matrix is formed which is optimal for the growth and maintenance of the bacteria.

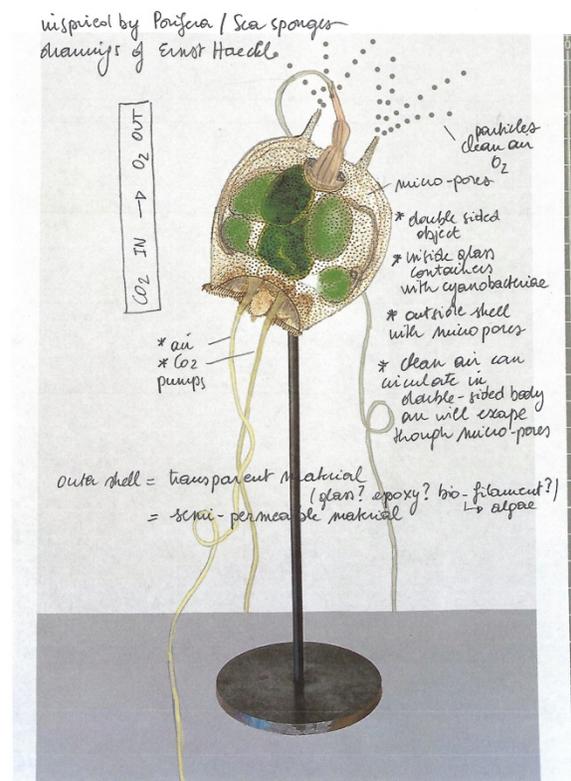
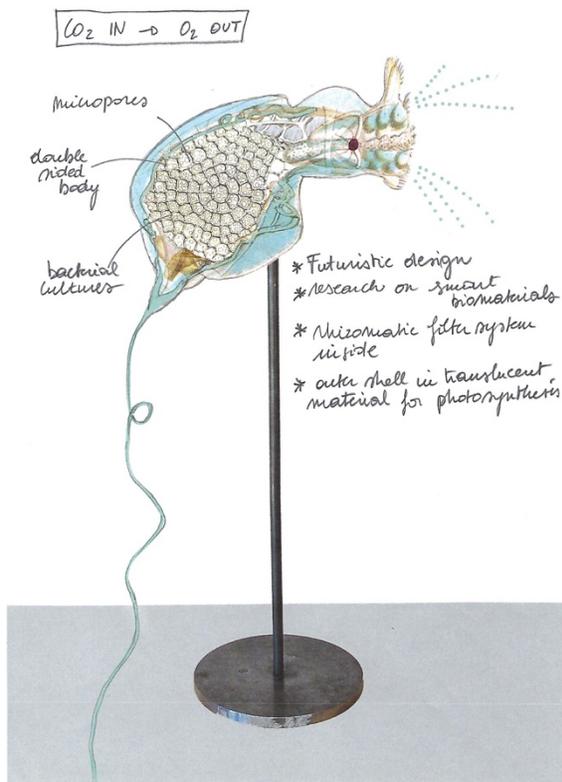
The different experiments with 3D prints and biofilms will lead to independent bio-artworks, not only in the form of images but also in the form of objects where parts of the pump/cleaning mechanisms can be experimentally tested. Additional artworks will document the research process - showing artifacts used during experimentation, mock-ups, partial results, design sketches, visualisations, models for 3d printing. They will convey the fascination and excitement of the scientific research and the beauty of the natural world of bacteria and sea sponges.

Planning

- Fieldwork will be carried out in the Laguna of in Venezia, where I collaborate with researchers from ISMAR /Istituto di Science Marine. I have already set up an 'herbarium' of *Algae* and *Porifera* to study the organisms in detail in my DIY bio-StudioLab in Brussels
- Herbarium + Sketchbook with a lot of drawings, studies about the biological mechanisms, the constituents and the materials
- Translation of the drawings and sketches in 3D drawings for modelling at the FabLab
- Detailed (partial) 3D prints and CNC milled and laser cut prototypes of forms and designs
- Molding and casting of forms in different materials as plaster and bioplastics
- Study of the pump mechanism of a sponge and translate it with simple DIY electronics to reconstruct an airpump where CO₂ goes in and O₂ comes out
- Adding the bacterial cultures
- Assembling all parts into a working prototype of a CO₂ reducing sponge-inspired object

Technical Drawings

- first technical drawings for a CO₂ reducing art object. Principle is: CO₂ IN => O₂ OUT
- forms can still completely change after thorough research
- inspired on the drawings of Ernst Haeckel; *Hydatinaea*
- body of the object is double sided
- inside is pump system for cyanobacterial culture doing realtime photosynthesis
- outside is a solid translucent shell filled with micro-pores
- intake of CO₂ at the bottom (water & air pumps)
- release of oxygen at the top and through micro-pores on the body
- there will be a study to work with biodegradable organic materials, as e.g. algae filament for 3D printing



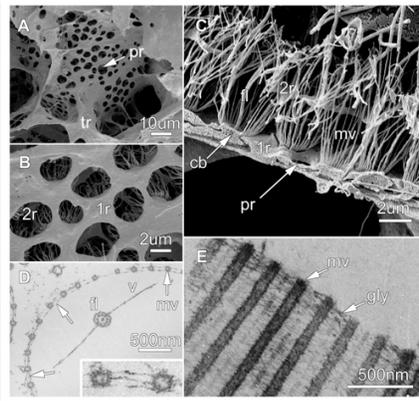
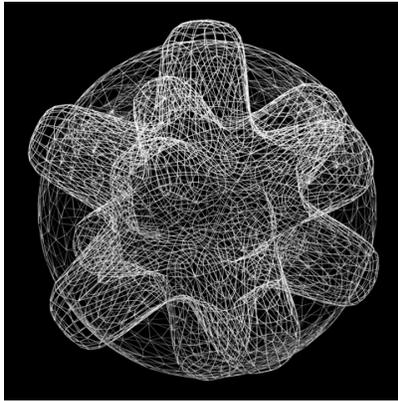


Fig.10: *Euplectella aspergillum* (Venus' flower basket) Fig.11: 3D drawings in Blender. Analyses of structures Fig.12: the fine structure of the filtration unit, electron micrographs of Sea Sponge mechanism

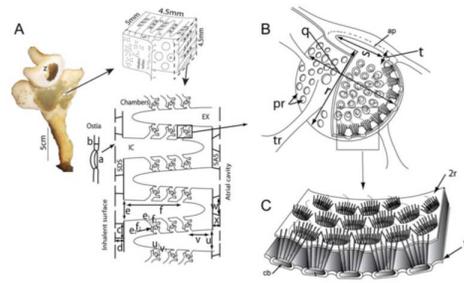
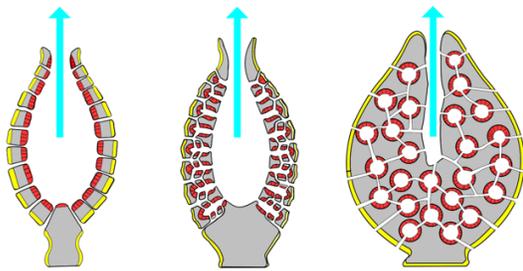


Fig.13: Flow diagrams, scheme for peristaltic pumps Fig.14: Flow and filtration apparatus of the Sea Sponge

- study of *Porifera*-tissue under the microscope to define the design in detail
- study of the flow mechanisms for implementing the peristaltic pump in the object
- study of the filtration inside the searsponge/object

Personal Statement

I am an artist, herbalist and beekeeper who has been studying the close interactions and co-evolutions within urban ecosystems. My research practice combines art and science, and I have a keen interest in DIY technologies and biotechnology. Since many years I work with a range of biological, digital and traditional media, including live organisms. My artistic research is materialised in techno-organic objects that are inspired by factual/fictional stories; in artefacts that are a combination of organic matter, digital fabrication and craftsmanship; in installations that reflect both the problem and the (possible) solution; and in multispecies collaborations, in polymorphic forms and models created by eco-data and in collaboration with micro-organisms.

Coping with the increasingly visible climate and ecological crises has become an important priority for humanity and it is now on top of the agenda for science and society in many countries. It should also be for art. For the past decade, I have been researching and carrying out art projects to raise ecological awareness and thus induce this behaviour change. On the rooftop of my studio in Brussels, I have created an open-air lab and an 750m² experimental garden, including a greenhouse, as a place for experiments with models of permaculture and social collaboration. I study living systems, natural networks and dynamic ecosystems and the processes that Nature employs to create form. My research as a naturalist provides an ongoing source of inspiration for my artworks as well as for my long-term research projects 'the Bee Agency', 'Sensorial Skin' and 'the Laboratory for Form and Matter'.

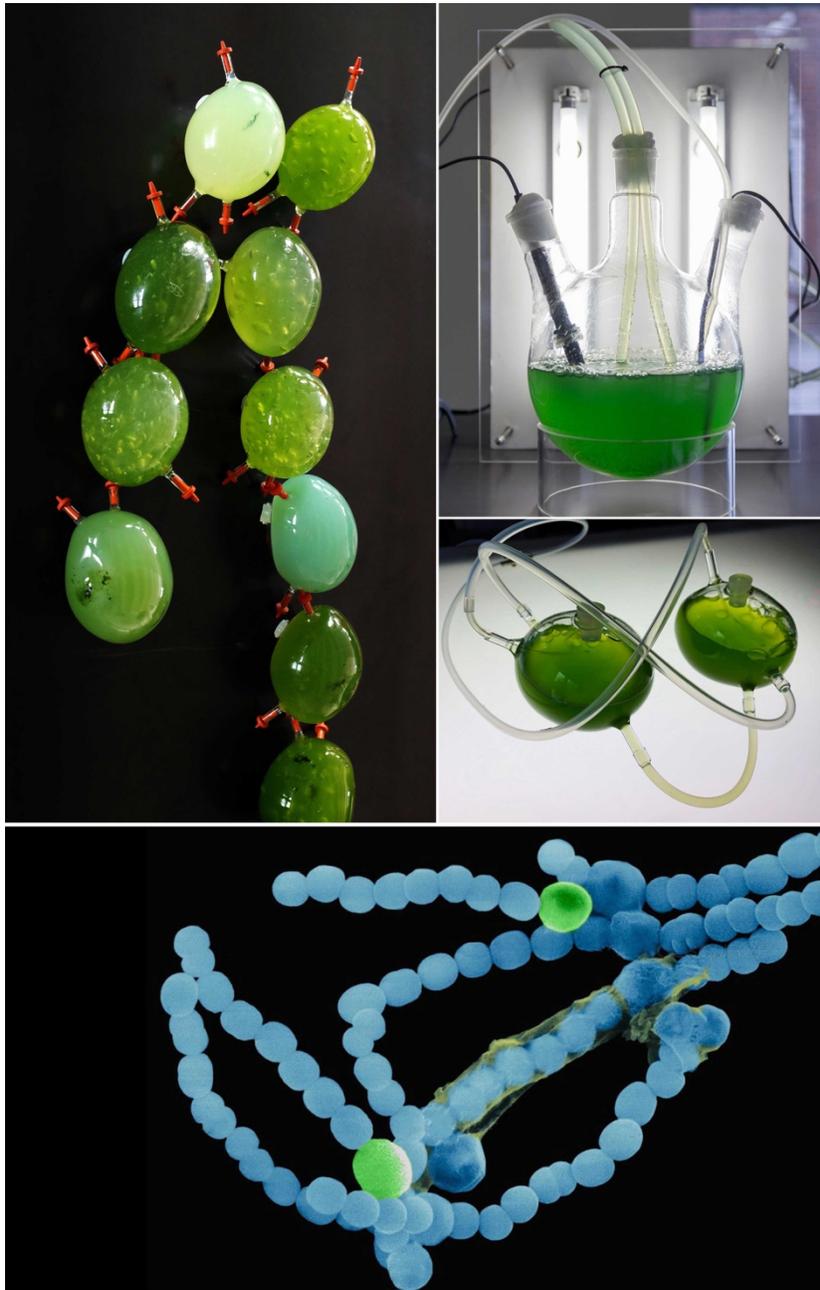
My flagship project is a series of sustainable beehives, called 'Intelligent Guerrilla Beehives'. Some of these beehives are presented as speculative designs/objects, but others are fully materialized and put into operation with live bees. These hives are not only creating a supportive environment for bees but they also allow observation through internal infrared cameras, temperature and humidity sensors, movement sensors, etc. They study the embodiment of the bee colonies into the urban landscape. The collected data is turned into meaningful information through signal processing, artificial intelligence, visualisation, and simulation.

I am an eager student in Materials Science and I am completely captivated by smart materials provided by Nature. My experiments with bacteria, algae and living textiles provide a framework that has inspired a wide range of installations and sculptures that can be seen as an artifacts from the future, as fragments of a world to come. Some of these artworks are installed in public spaces, others have been shown as installations, sculptures, objects and videos exhibited in prestigious venues in many European countries and in art centers worldwide. I am rewarded with various prizes, such as the Ars Electronica honorable mention in the category 'Hybrid Art' in 2017. Important grants for residencies gave me the possibility to deepen out my research and to strenghten my international partner network. Fieldtrips, workshops and residencies at the IAAC Fab&Textile lab in Barcelona (2016), the Finnish Bioart Society in Kilpisjärvi (2018), an innovative-partnership residency at the Open BioLab in Brussels (2019) and a STARTS-residency at the Hybrid Forms Lab at the VU Amsterdam (2019-2020) were ideal places and formats for learning, collaboration and for further development of my projects.

I am currently developing my Sensorial Skin project, with a focus on micro-algae, cyanobacteria and seaweeds and I plan to continue my explorations into the incredible potential of these natural resources with labs in Barcelona (Institute of Marine Sciences /CSIC) and Venice (ISMAR /Istituto di Science Marine). I am particularly eager to focus my ecological research on the study of symbionts (as e.g. the cohabitation of algae & fungi in lichen) and I want to compare the benefits of different (aquatic) ecosystems to further develop my bio-sensorial objects.

Info on my work and my artistic projects can be consulted on my website: <https://annemariemaes.net/>. A portfolio with selection of works can be visited here: <https://annemariemaes.net/portfolios/> and a short video introduction to my artistic practices can be consulted in the movie '[Alchimia Nova](#)'.

Selected documentation of previous projects



OBSERVING CYANOBACTERIA

Fig.1: Left: L'Origine du Monde, Bacterial Chain Fig.2: Right: Cultures of Cyanobacteria(Synechocystis sp.)

In our Open Greens Observatory, we will set up some cultures with cyanobacteria. Cyanobacteria obtain their energy through oxygenic photosynthesis. They consume the CO₂ from the air and they release oxygen, similar as plants do. These photosynthetic microorganisms are found in aquatic environments where they form the base of healthy food webs and participate in symbioses with other organisms. The cyanobacteria are the first bacteria of our oxygenic universe, the basis of evolution.

In my installation 'L'Origine du Monde' I work with cyanobacteria. The set up shows a strongly enlarged bacterial chain made from glass cells. Every cell is filled with cyanobacteria producing realtime photosynthesis, and thus cleaning the air. The cyanobacterial colonies are growing little by little and their color becomes more dense green over time. After a few weeks of culture we can harvest the green pigments and use them for e.g. coloring our microbial-grown textiles.

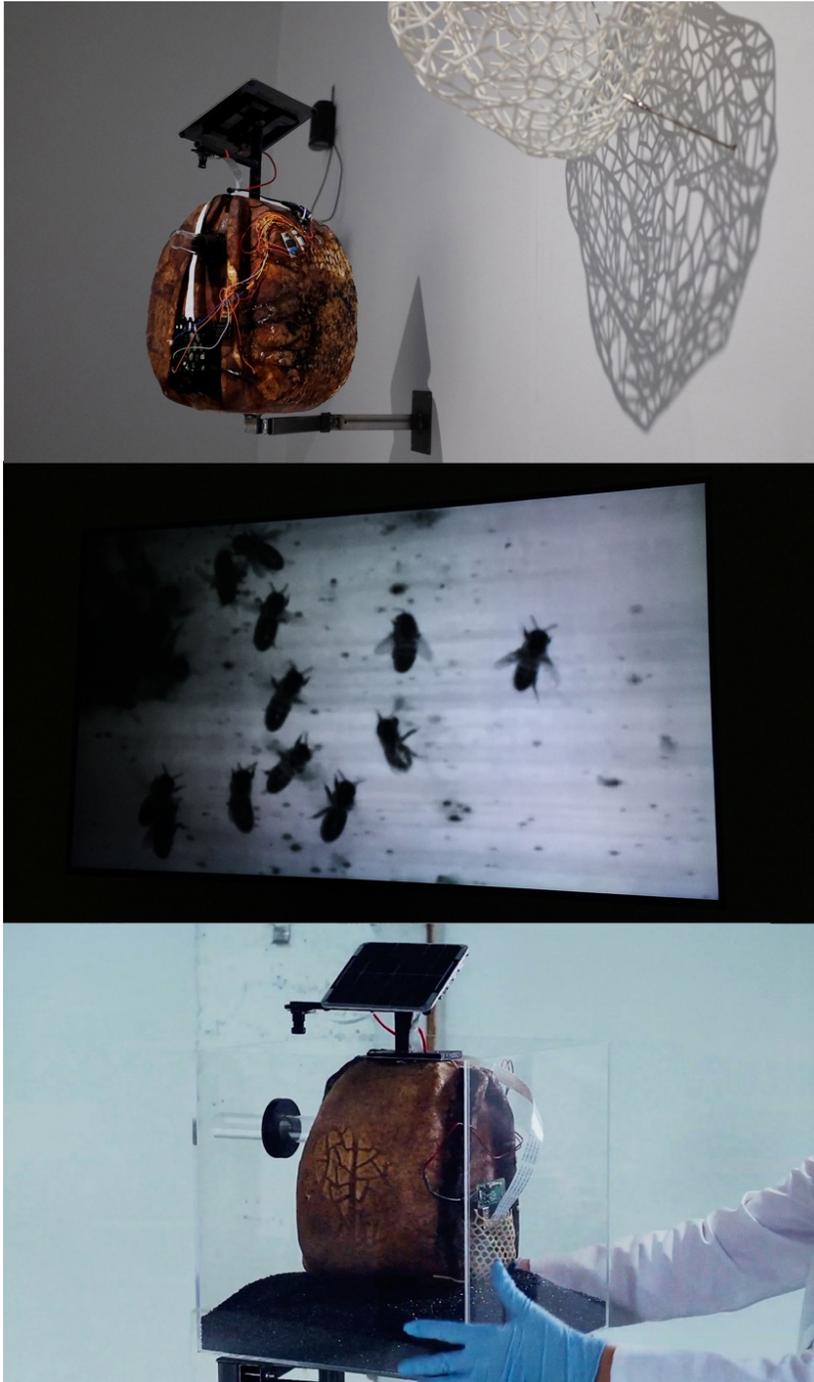
<https://annemariemaes.net/works/bee-laboratory-works/lorigine-du-monde-installation/>
<https://annemariemaes.net/works/bee-laboratory-works/electric-veins-object/>

BEE AGENCY

Fig.2: The Intelligent Guerrilla Beehive, selection of prototypes from the research (2016-2019)

The Intelligent Guerrilla Beehive is a research project on the edge of art and science. It evokes issues of sustainability and biodiversity, giving viewers an artistic experience of my ongoing research related to the disappearance of the honeybee. The goal of the Intelligent Beehive is a double one. At one hand it offers a safe refuge for city honeybees, and at the other hand is is a biosensor that interacts with the environment and that measures the pollution of the foraging fields around the beehive.

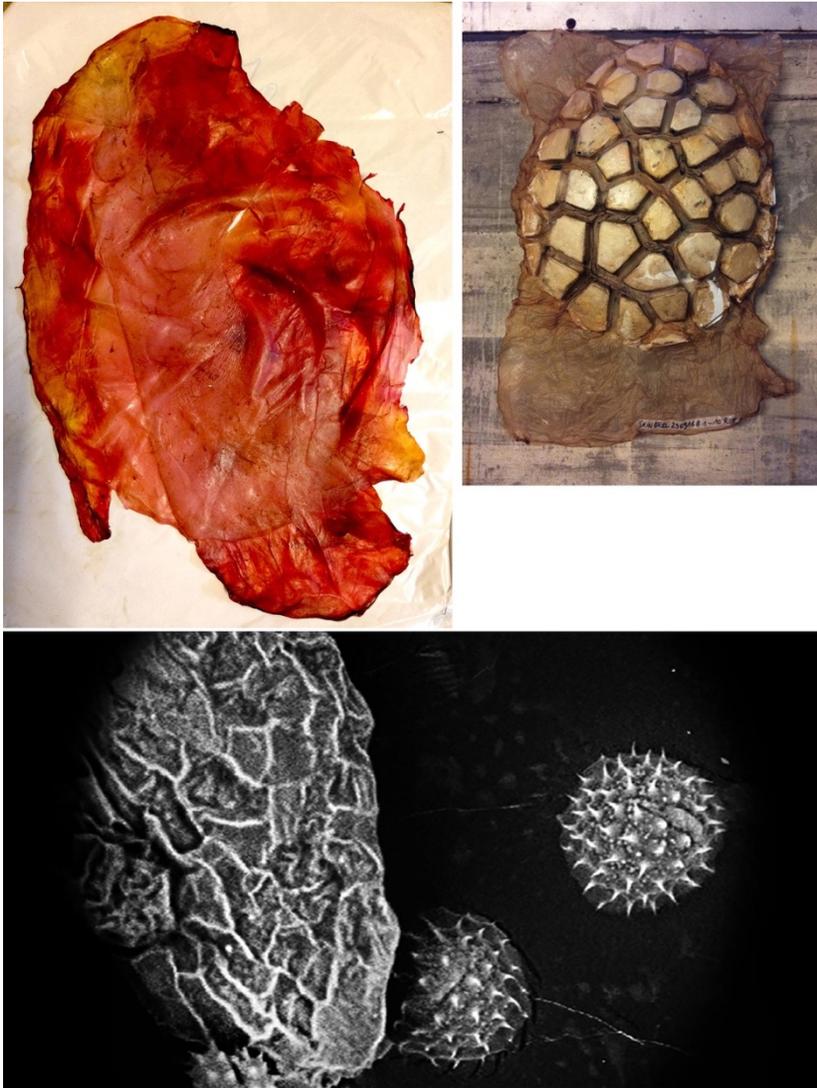
The project is a collaboration with the non-human other. Honeybees and bacteria become interfaces to be informed about the health status of our environment. Bees and bacteria become living monitoring technology.



<https://annemariemaes.net/projects/the-intelligent-guerrilla-beehive/>

SENSORIAL SKIN

*Fig.3: Genesis of a Microbial Skin
(2017-2020)*



'Close reading of the Genesis of a Microbial Skin' gives a condensed overview of my notes (related to the research on Intelligent Beehives and with a focus on smart materials, e.g. microbial skin) between 2012 to 2017. The project is about growing Intelligent Guerilla Beehives from scratch, with living materials – as nature does. Biomimesis is used as a starting point for incubating ecological thinking on matter and form. Different sensorial qualities of microbial and vegetal skin are being examined in terms of usefulness for sensing environmental threats and for monitoring the wellbeing of the bee colonies. The Lab experiments were carried out between 2012-2017: in the Brussels Bee Laboratory and the Laboratory for Form and Matter; in the DIYBio Barcelona and the University Pompeu Fabra in Barcelona; and in the lab of Chemical Engineering of the University Brussels (VUB) with the SEM (Scanning Electron Microscope).

<https://annemariemaes.net/projects/genesis-of-a-microbial-skin/>

SENSORIAL SKIN



Fig.4: Working with Bacteria in the Laboratory for Form & Matter (2016-2020)

The Laboratory for Form and Matter is a research project into artistic practices in the post-digital and post-media era. It is situated at the intersection of biology, ecology, technology and contemporary culture. The research is fed by my interest in bacteria as a medium for artistic expression and by a certain fascination for natural structures and organic processes at microscopic level, such as the collaboration in bee colonies and the strength of fungi networks. The artistic precipitation of this research crystallizes in the creation of objects and installations, and by giving workshops, presentations and performances. For the artistic research the following techniques are used: digital fabrication, 3D printing, laser cutting, traditional modeling techniques, creation of textiles with plant materials, creation of biotextiles with microorganisms, research on intelligent biotextiles by adding biofilms with bacteria, research on implementation of artisanal, industrial and organic materials in artifacts, ...





LABORATORIUM OF FORM&MATTER

Fig.5: Top - Laboratorium table (part of the installation) in 'Eco-Visionaries' at Laboral, Gijón (es)

Fig.6: Middle – (part of the) Presentation 'Intelligent Cities' at MAAT (museum for Art, Architecture & Technology).

Fig.7: Bottom – Bozar Brussels, Generation Z

The images to the left are an example for the 'feel' of the *Laboratorium Aesthetics* that will be applied for the installation *Connected Open Greens*.



I have a collection of metal tables and pedestals, all mounted following similar 'open structures' principles.

I would like to construct similar hardware elements in the *Connected Open Greens Observatory*, to create an installation which consists of a multitude of small experiments, possibly set up in collaboration with local inhabitants.

Observing compost degradation by micro-organisms (compost brought in by local inhabitants); set up soil diversity observation test with mud and water from L'Ourcq; grow our own mushrooms and make eco-material out of the mycelium rhizomes; ferment products of the garden into new organic fabrics and bioplastics, ...

Possibly, the installation can be accentuated with some (small) Scanning Electron Micrographs (mounted on aluminium support) that I made from pollen grains and dissected honeybees.



<https://annemariemaes.net/presentations/bee-laboratory-presentations-2/2019-eco-visionarios-at-laboral-gijon-spain/>

<https://annemariemaes.net/presentations/bee-laboratory-presentations-2/2018-for-a-brave-new-brussels-at-maat-lisbon/>

FIELDWORK

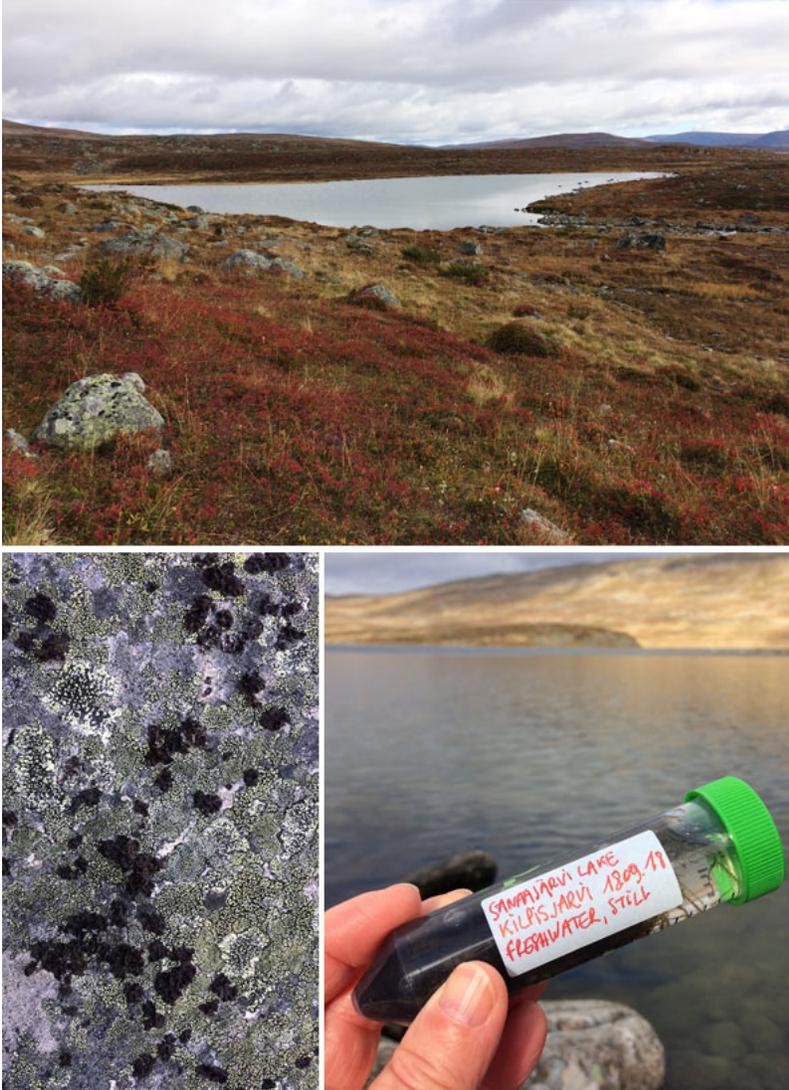


Fig.8: Fieldwork during fieldtrips in Kilpisjärvi, Finland (2018)

Field_Notes - Ecology of the Senses was an art&science field laboratory at the Kilpisjärvi Biological Station in Lapland, Finland. Organised by the Finnish Bioart Society, five groups worked for one week in the sub-Arctic Lapland to develop, test and evaluate specific interdisciplinary approaches in relation to the notion of Ecology of Senses.

This fieldtrip was an ideal moment to focus on the relation with Nature and with the other, may it be humans, animals, plants or microbes. A milestone in the development of my art/science work and the start of my focus on algae. It is with a similar focus that I would like to conduct fieldwork around Barcelona, in Collserola and Montseny, and study the collected samples in the wetlab of Hangar, in collaboration with local scientists, artists and designers.

Fieldwork, experiments, research and documentation on my research wiki.

<https://research.annemariemaes.net>