An Ecosophical intersection of algal biotechnology and design
Algaerium Bioprinter & Algae Printing

Shaping the Future 2017, ENSAD
8 Feb 2017

Dr. Marin Sawa
Designer/reseacher
Sir Ernst Chain Building, Life Sciences,
Imperial College London

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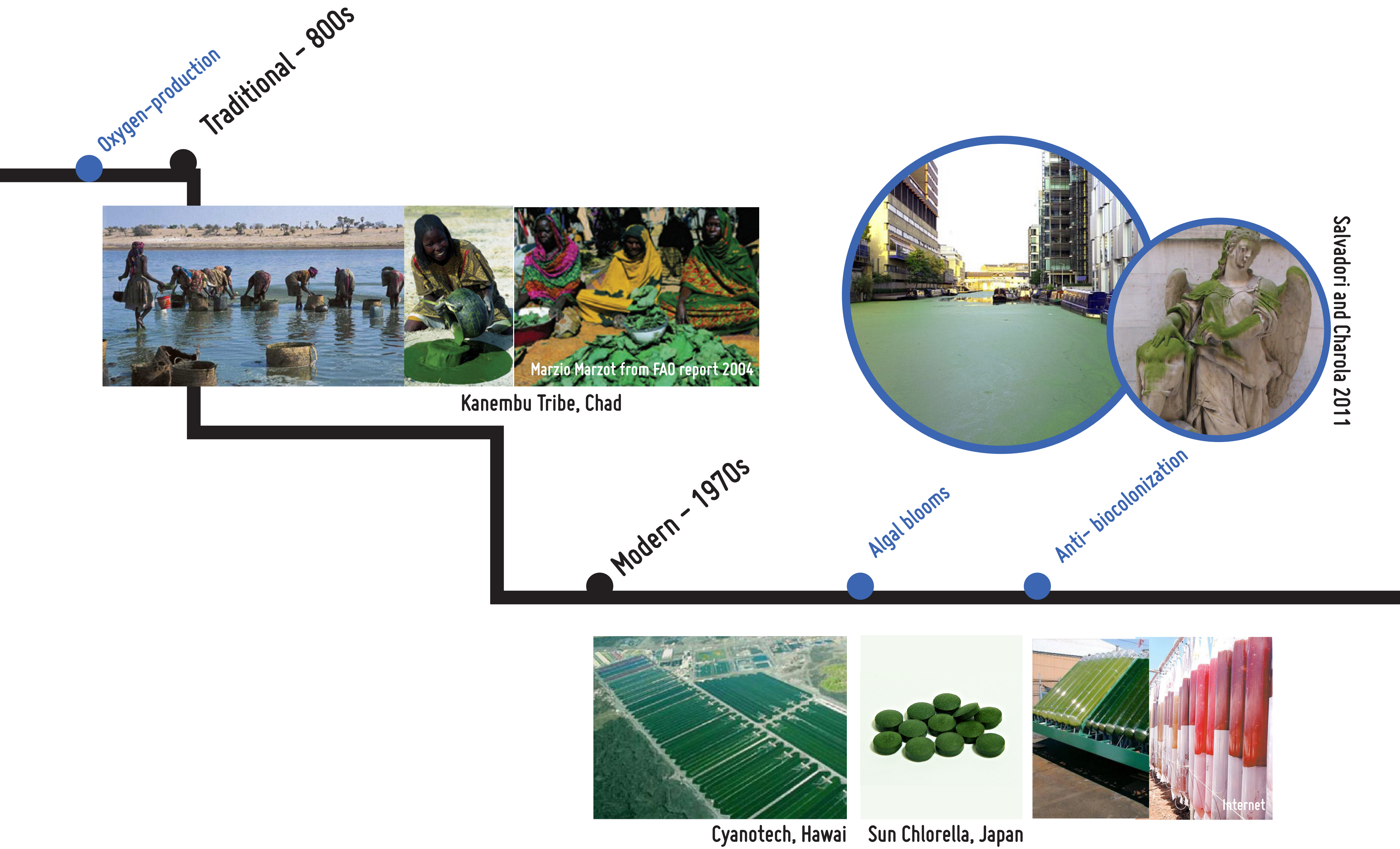
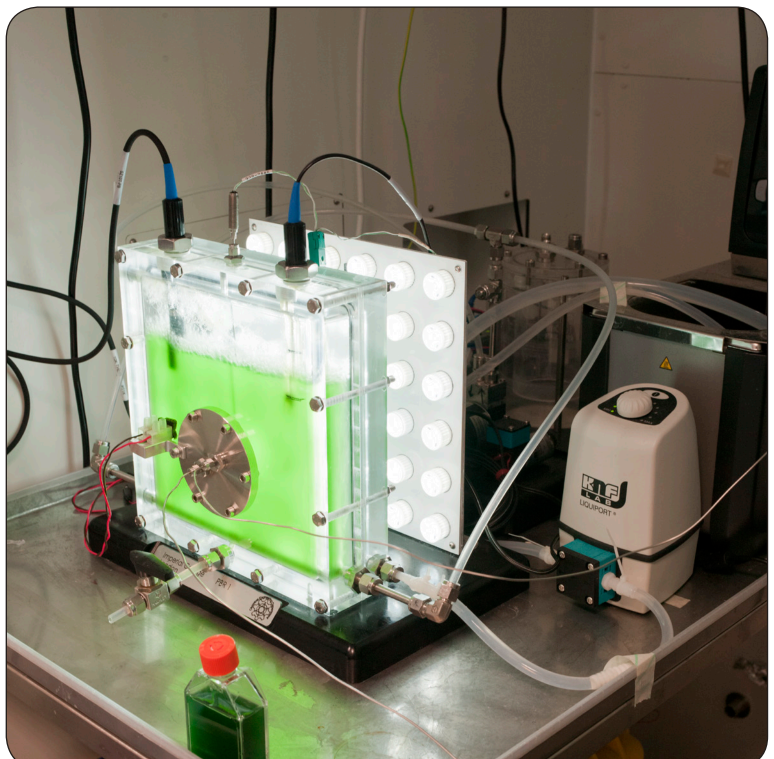
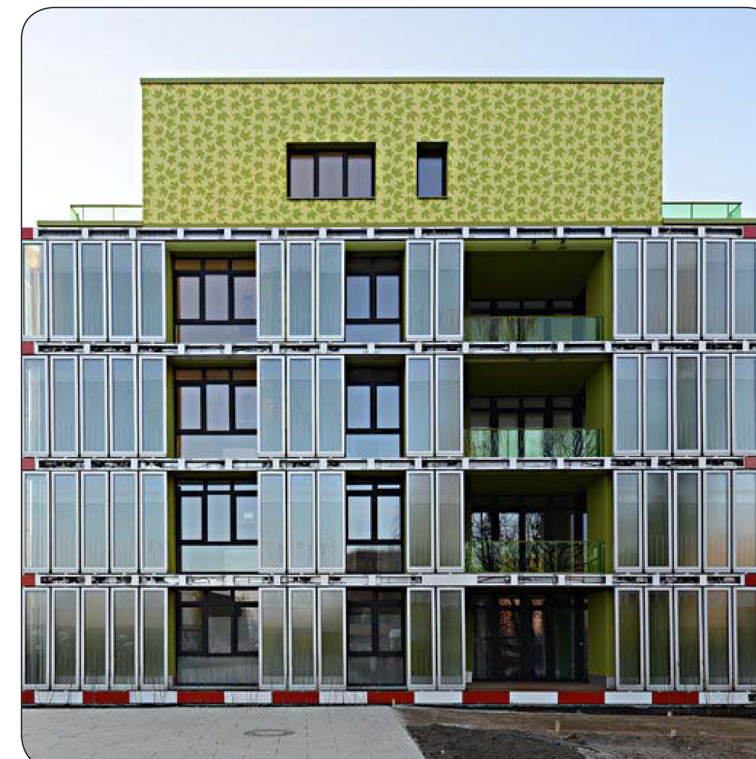
Microalgae: social and environmental





Marin Sawa



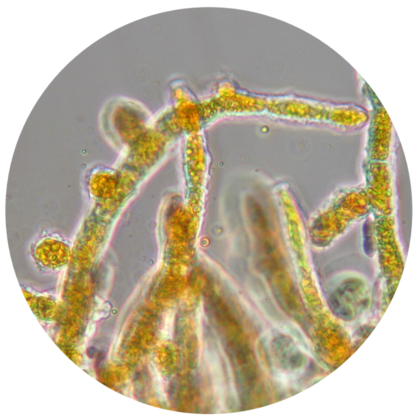
PBR Technology in R&D, 1980s –
Flat panel PBR by Prof Klaus Hellgardt group, Imperial College London (Energy Futures Lab)

Speculative design, 2006/7–
'Urban Battery, USA, 2007 by MOS Architects

Materialisation, 2013
The Bio Intelligent Quotient Building, Hamburg by Arup and Colt Group

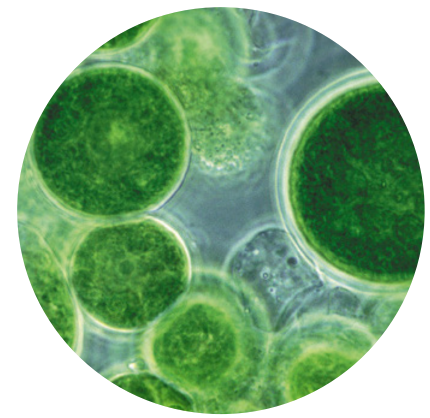
Terrestrial microalgae: diversity and extremophiles

Tree algae

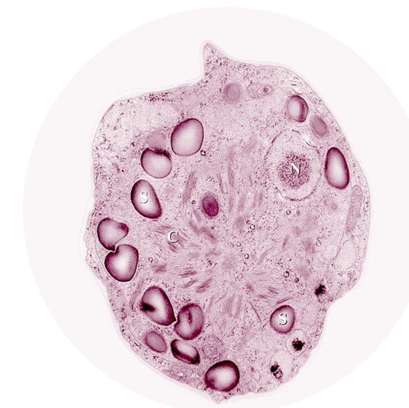


Soil algae

Desert stone algae



Snow algae



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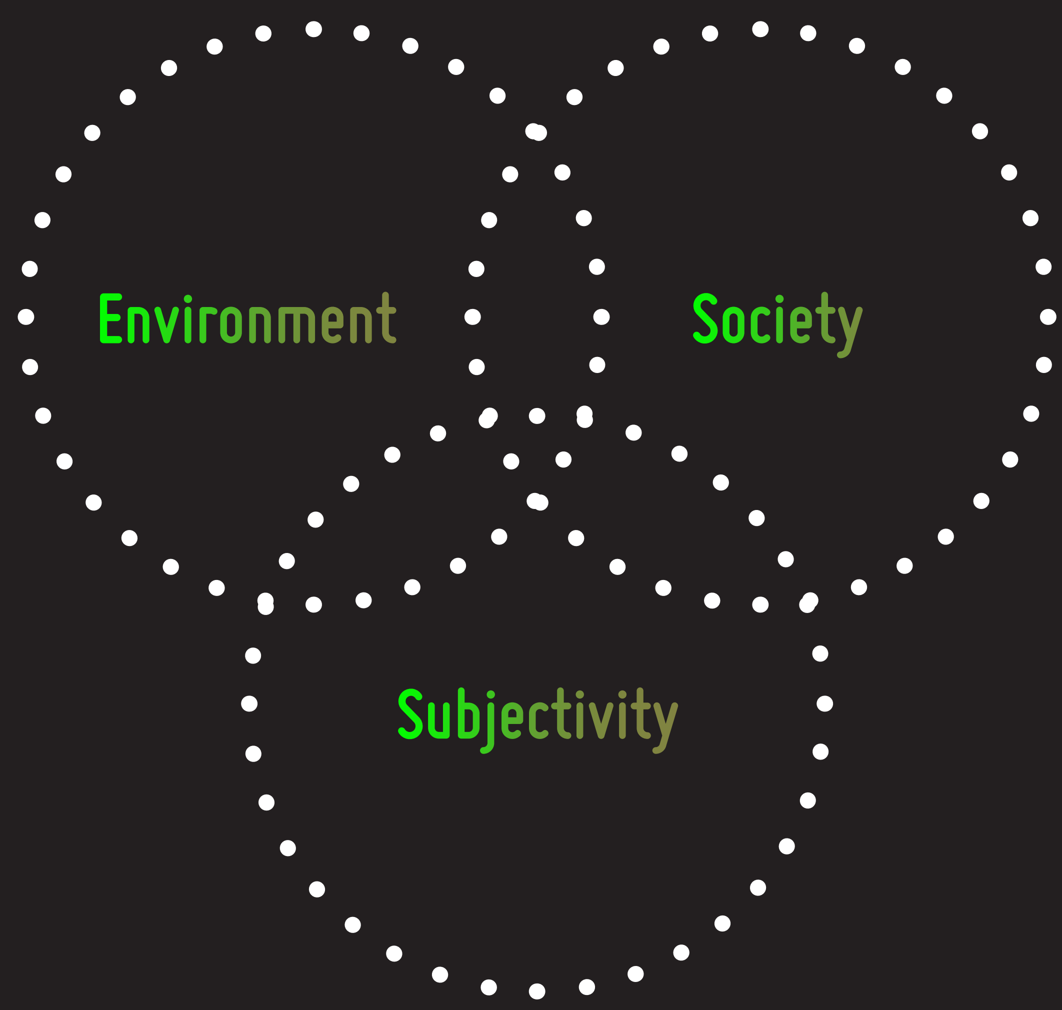
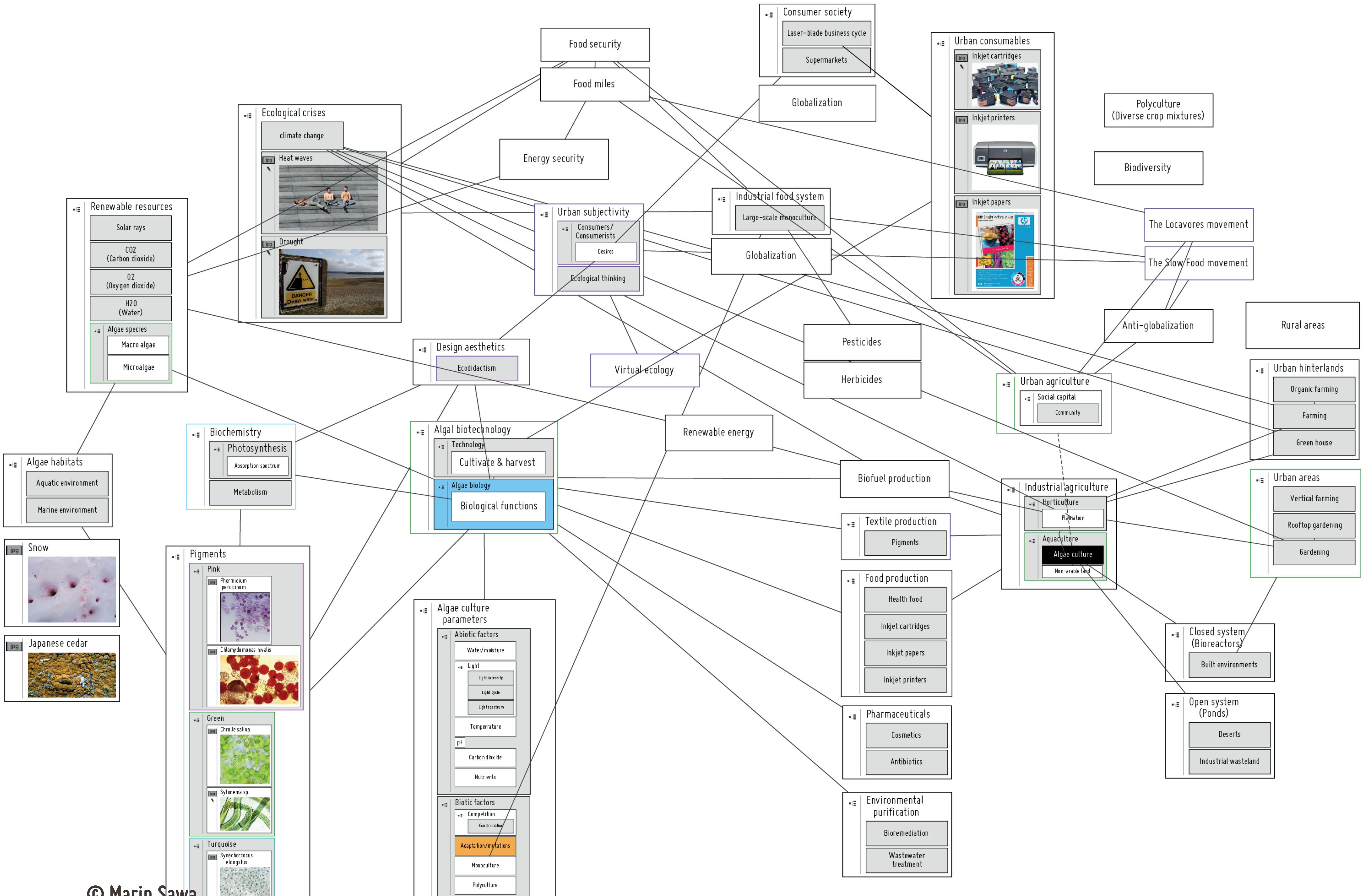
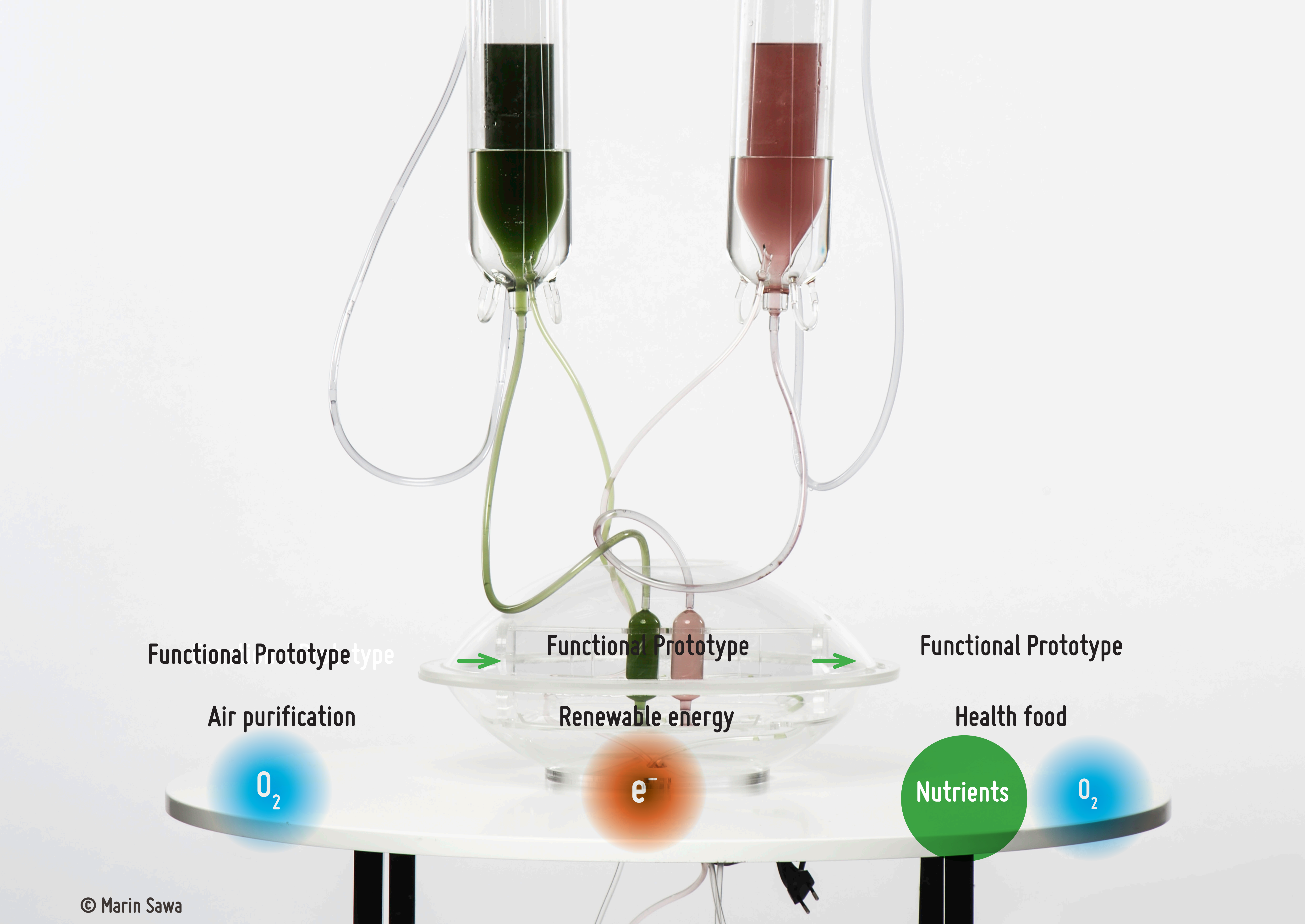
Here we are talking about a reconstruction of social and individual practices which I shall classify under three complementary headings...: social ecology, mental ecology and environmental ecology. (Guattari 2000, p.28)

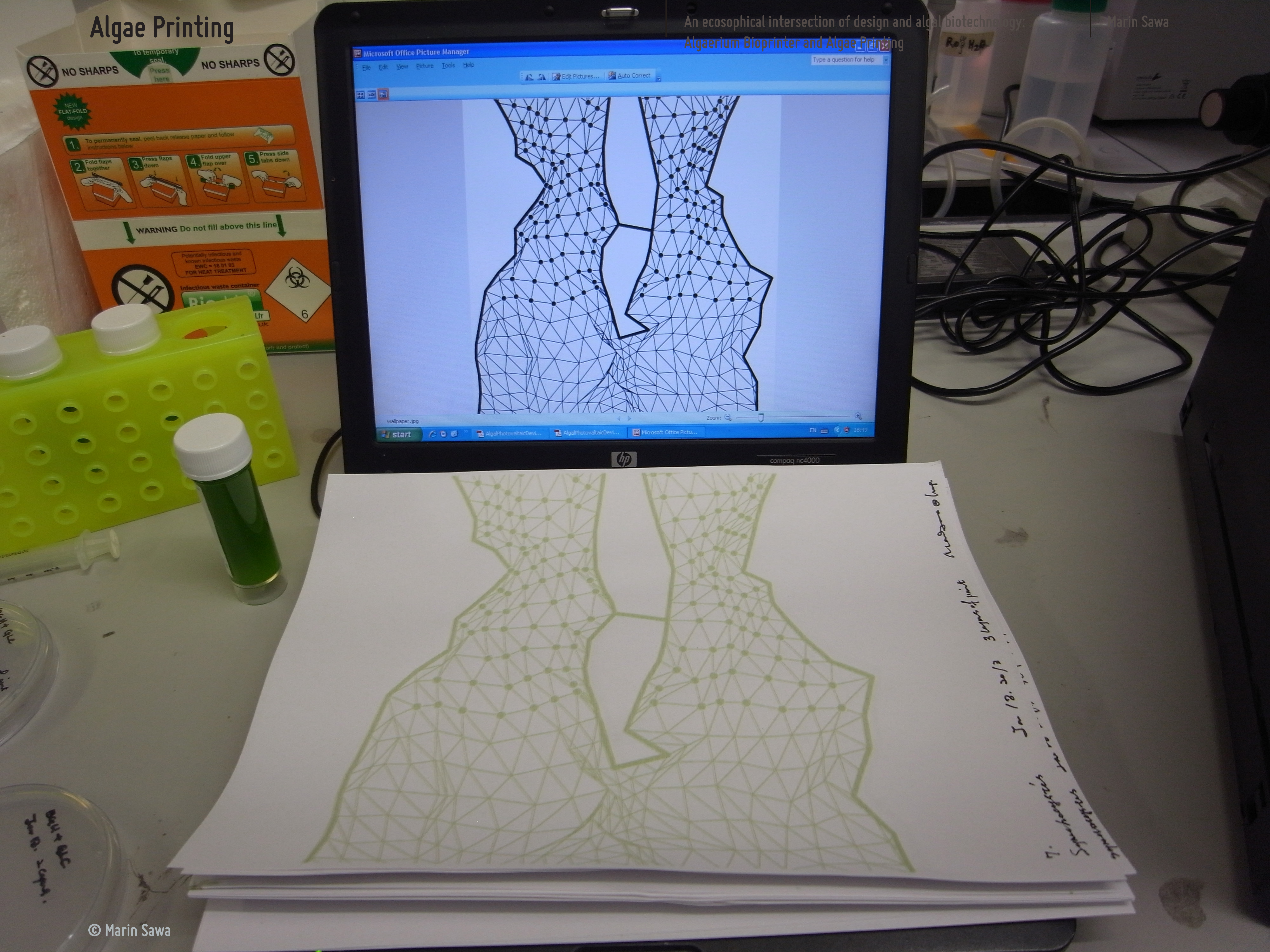


The inter-connections of the three ecologies or environments as an "ethico-political articulation" calling it ecosophy. (Guattari 2000, p19)

Ecosophical perspective on algal biotechnolgy




Functional Prototype
Air purification
O_2
Functional Prototype
Renewable energy
e^-
Functional Prototype
Health food
Nutrients
O_2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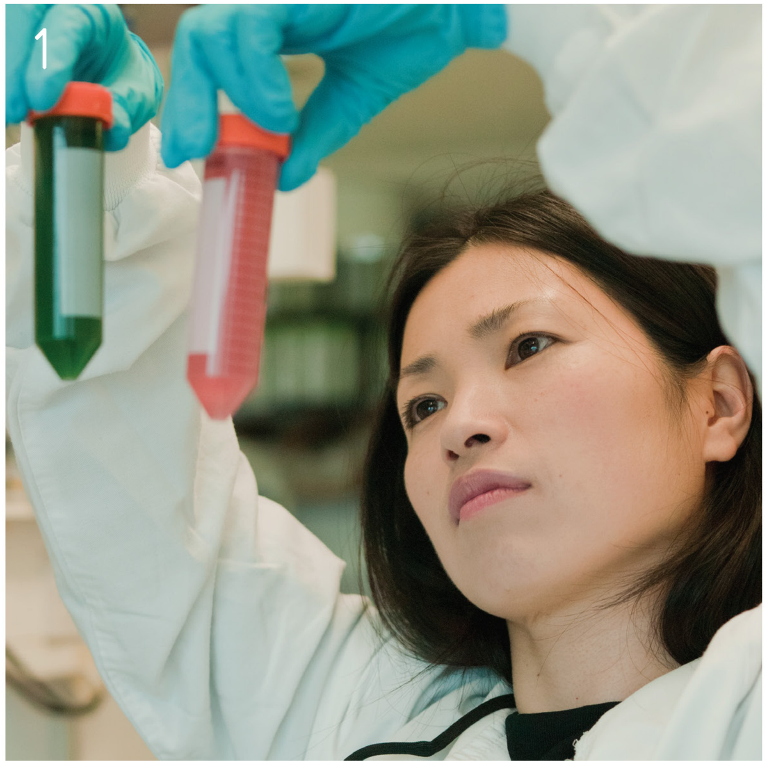
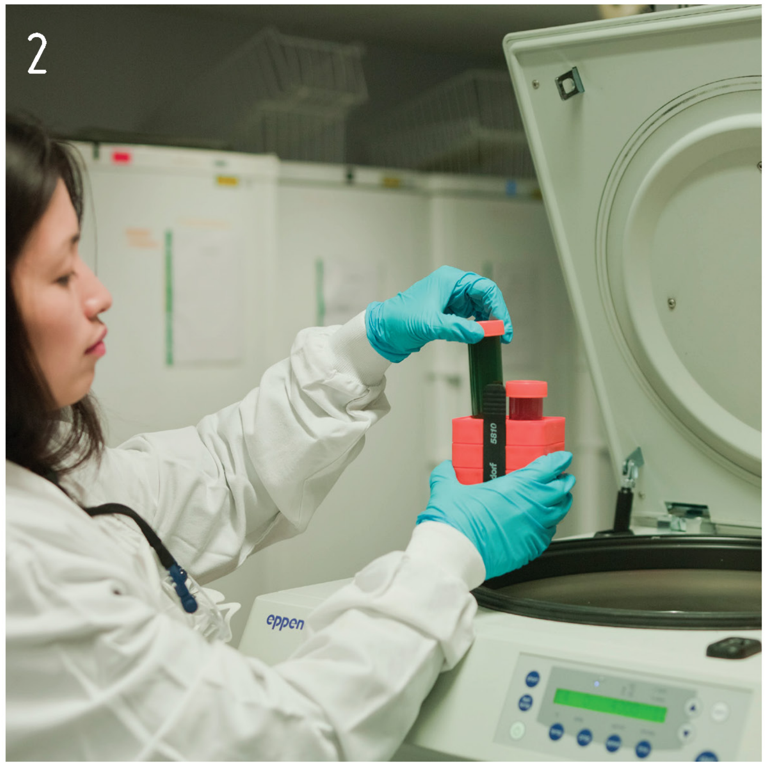
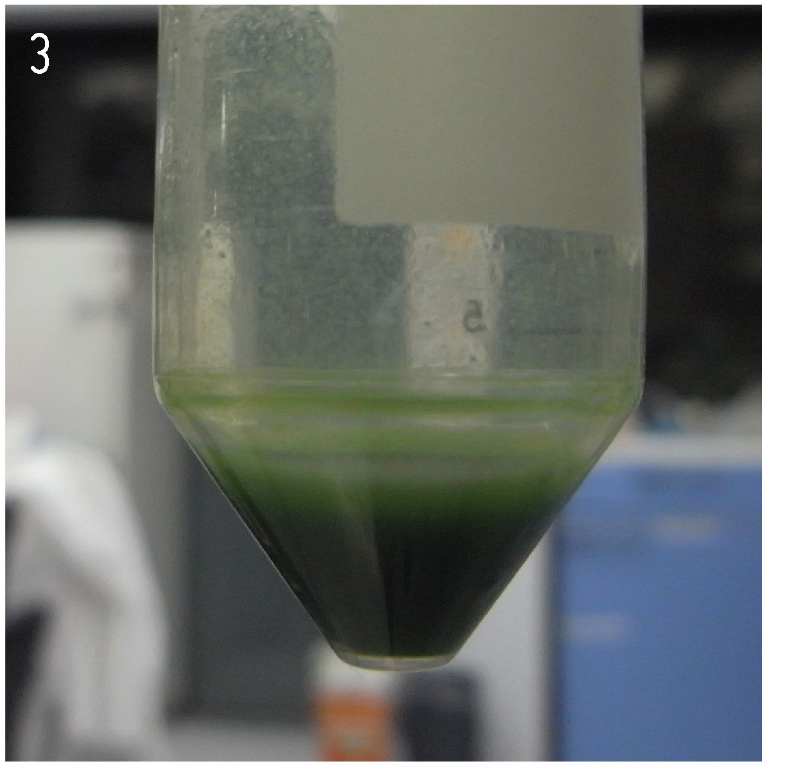
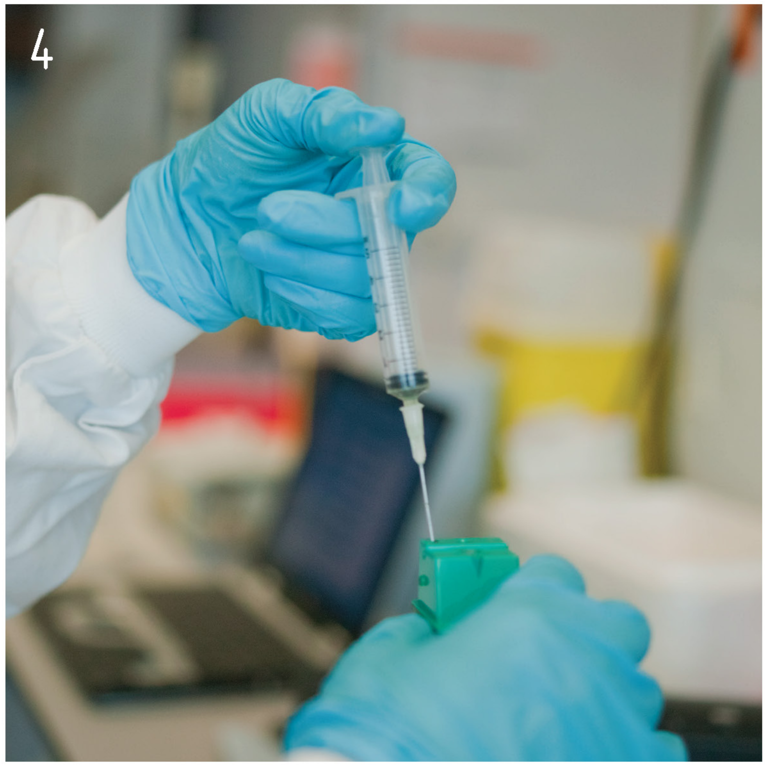
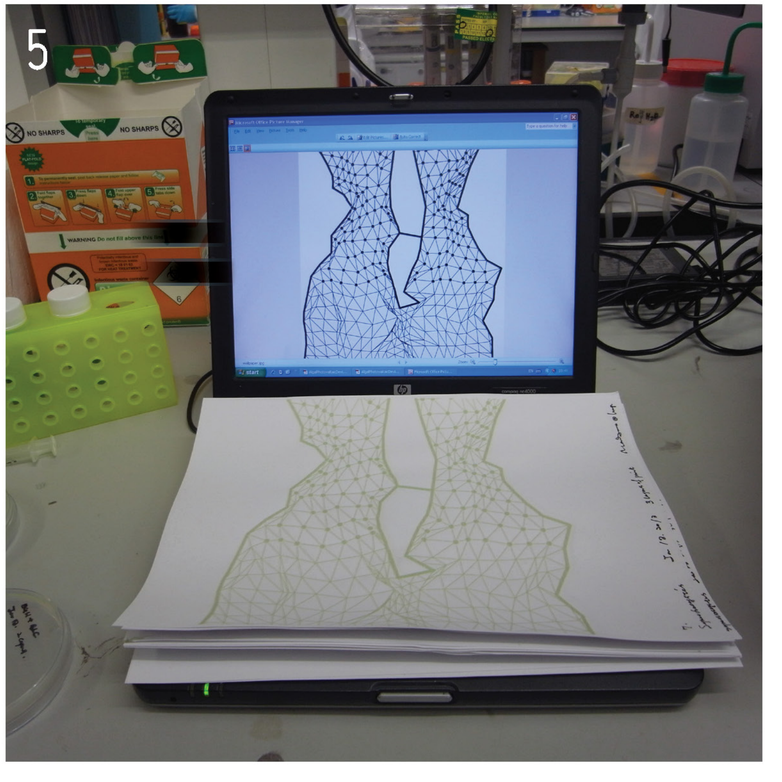
Printing process in the lab: making bioink

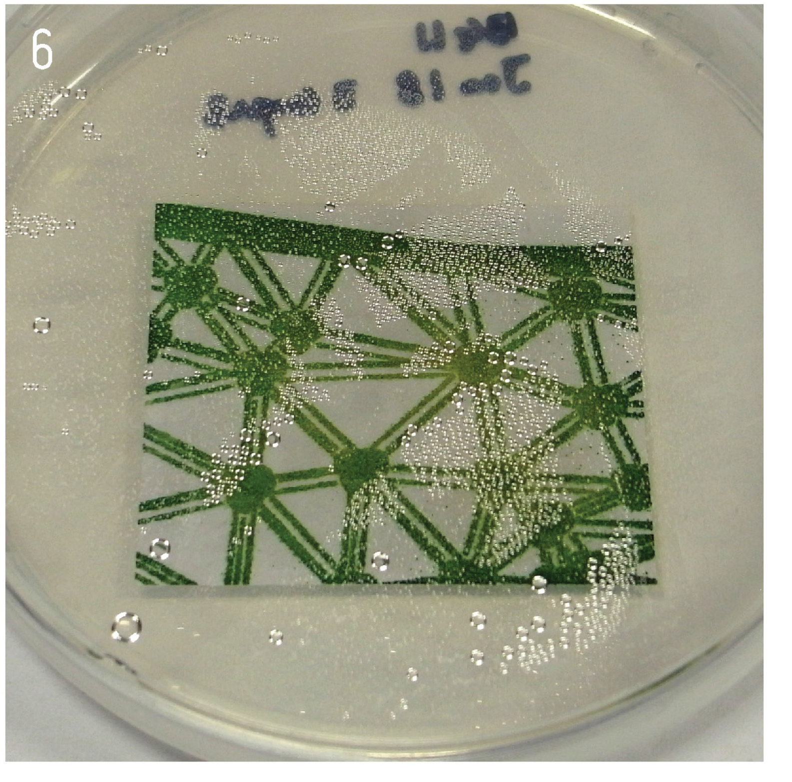








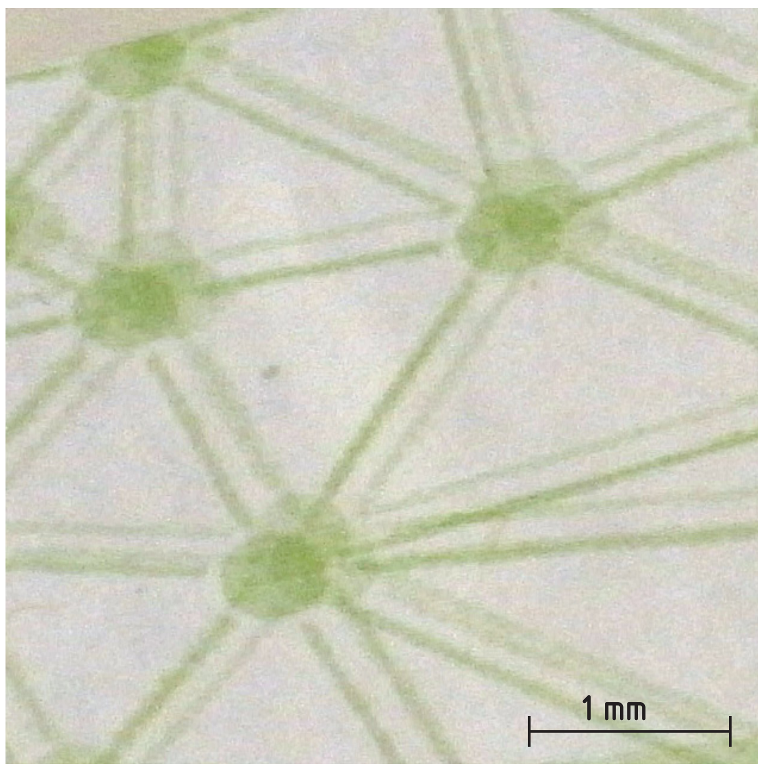




 – all experiments carried out in collaboration wtih Nixon Group at the Biochemistry lab. Imperial College London

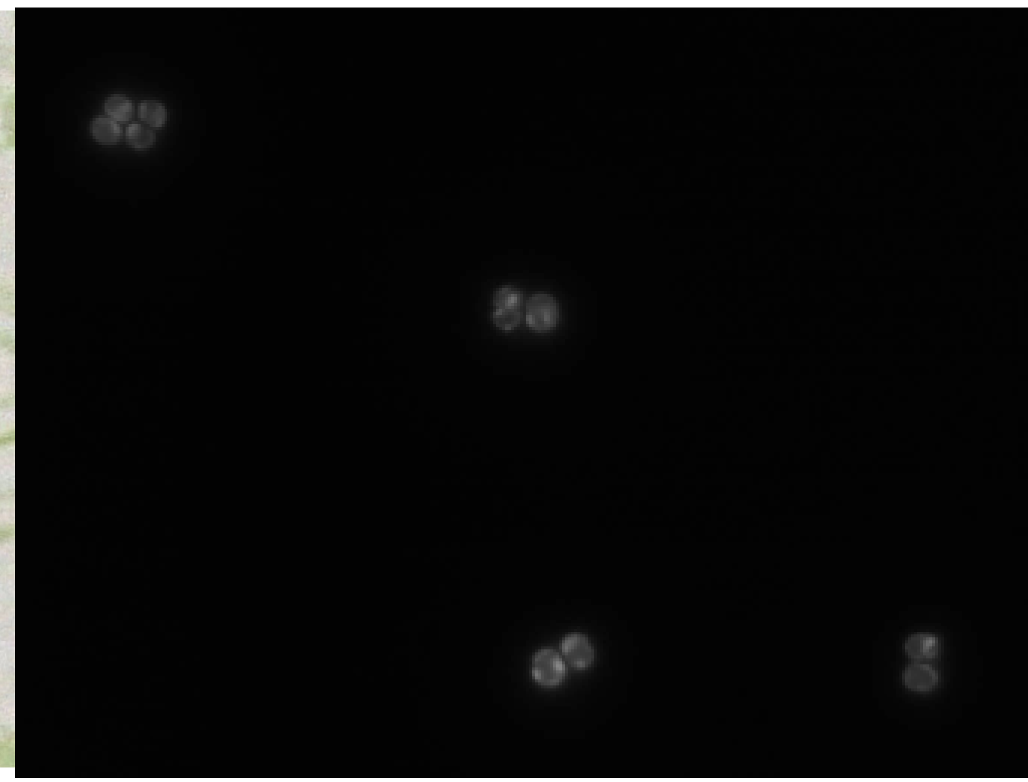
Microbial growth: solid culture

DAY 1



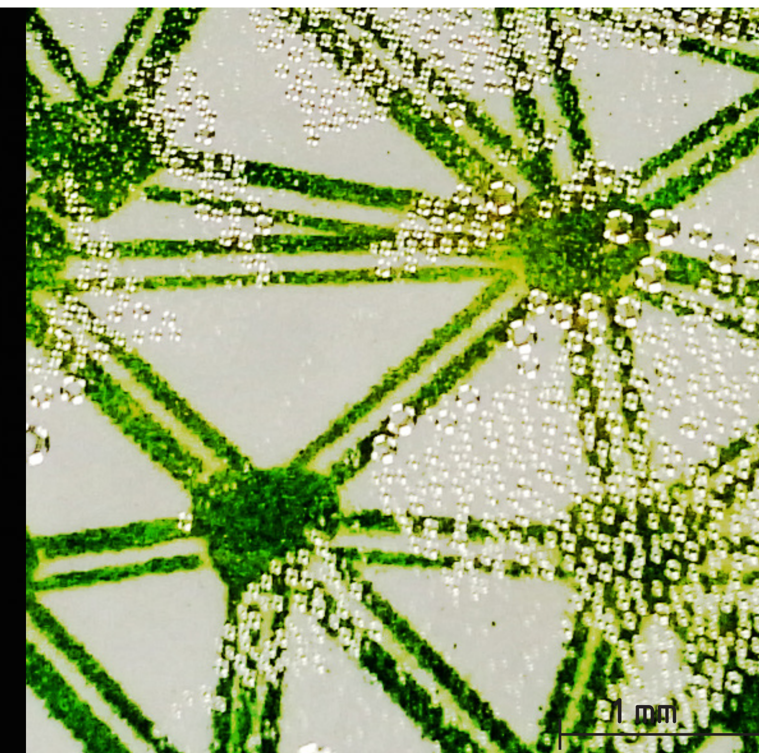
Cell Doubling

10 µm

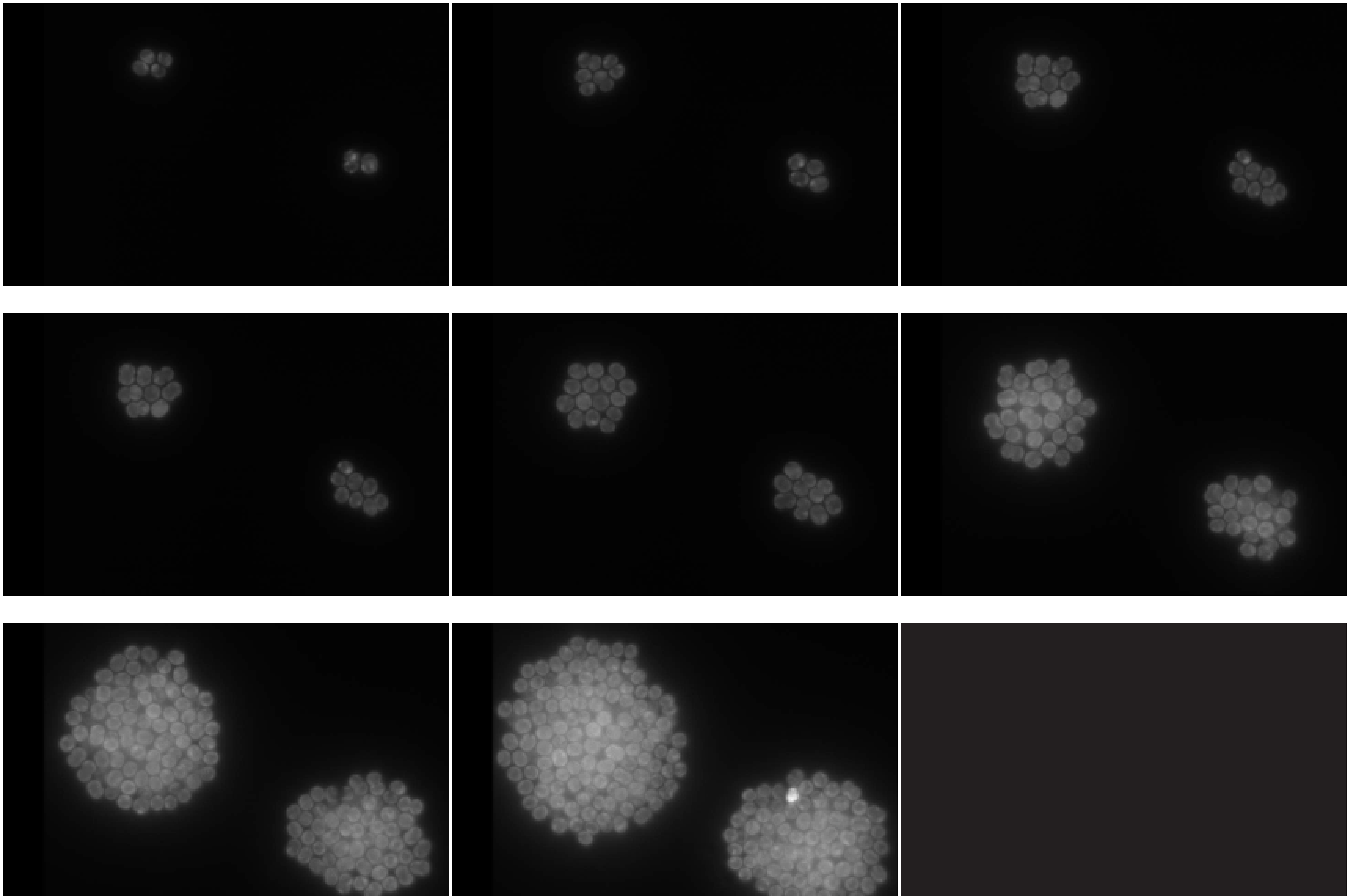


The video – courtesy of Dr David Lee-Smith (University of Cambridge)

DAY 7



Cell doubling: solid culture
(video stills by David Lee-Smith)



Proof of concept – digitally printed algae culture

Cell viability 98–99%

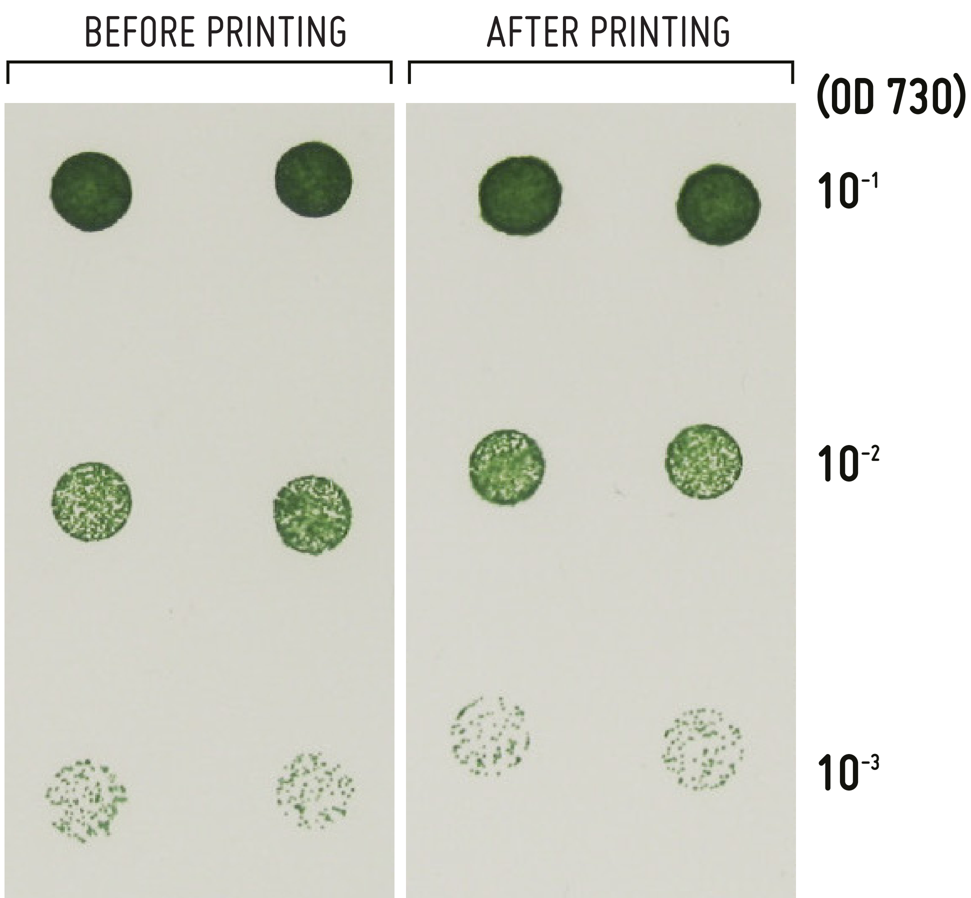
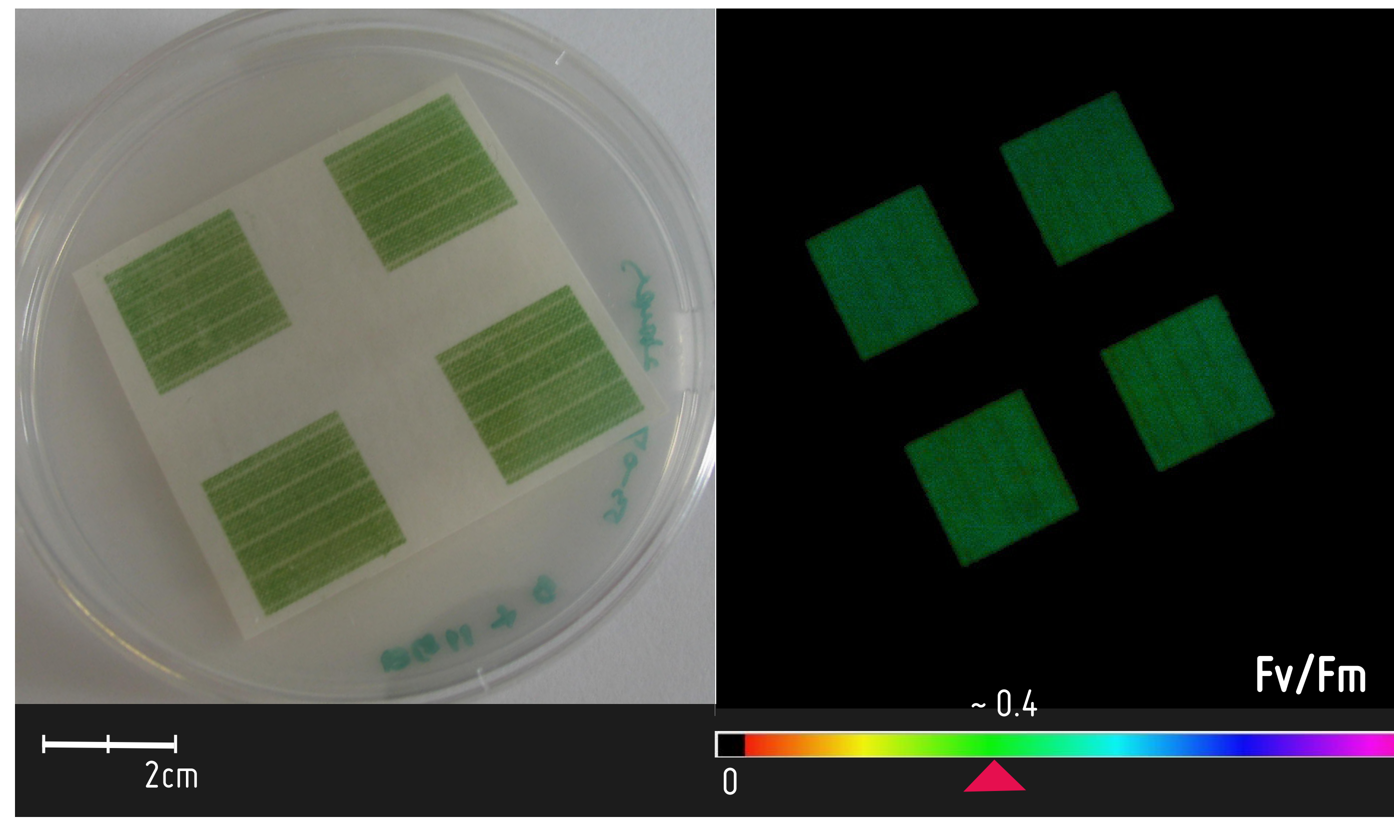


Plate analysis
In collaboration w/ Shengxi Shao, Prof Peter Nixon group (Imperial)

Chlorophyll Fluorescence Fv/Fm = 0.4 = Liquid culture (Suggett et al. 2009)



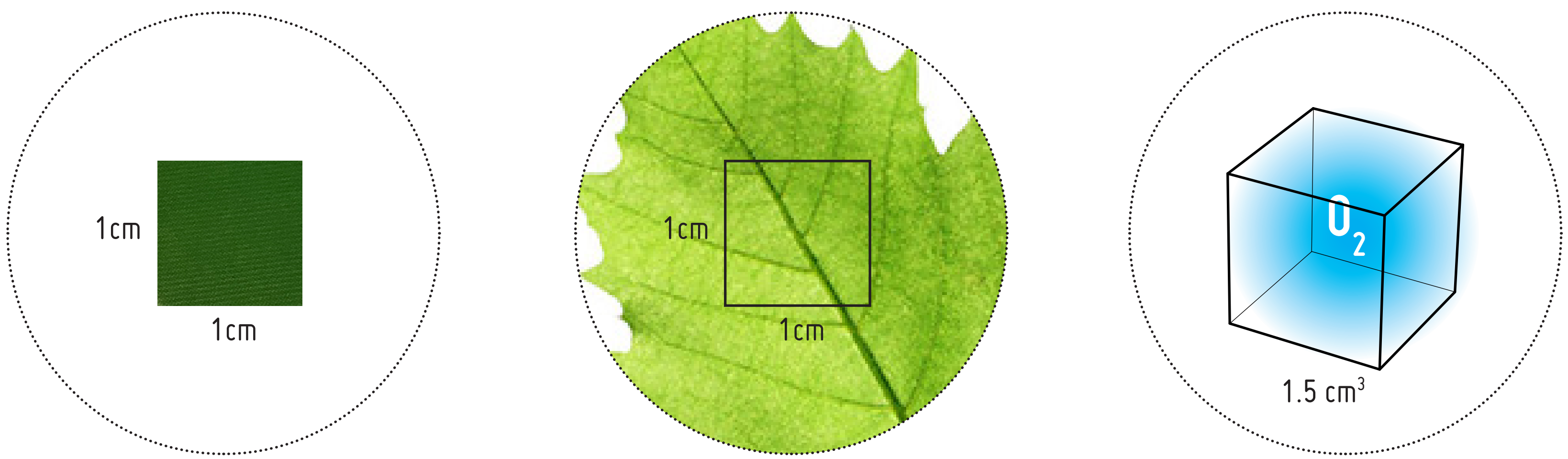
Imaging-PAM analysis
In collaboration w/ Dr Petra Ungerer, Prof Alexander Ruban group (Queen Mary University London), Dr Andrea Fantuzzi (Imperial)

Proof of concept – digitally printable oxygeneration and nutraceutical cell

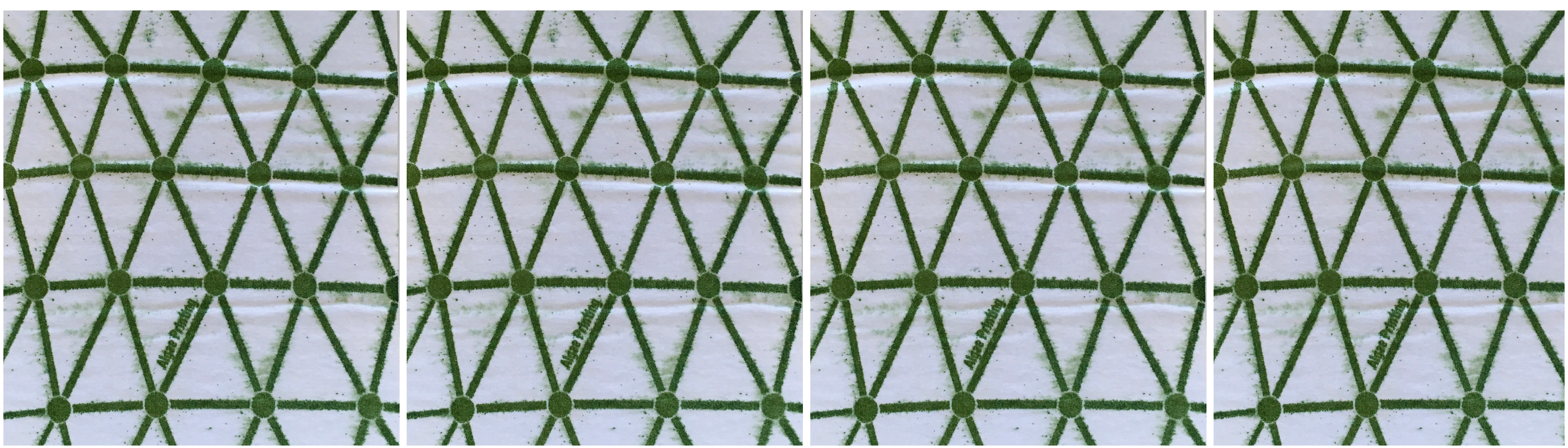
$1cm^2$ produces
50 micrograms of chlorophyll
μg: (1×10^{-6}) of a gram

$1cm^2$ = Plant leaf
(McMillen& McClendon1983)

$1cm^2$ produces
1.5 millilitre of oxygen/12 hrs
ml: (1×10^{-3}) of a litre; $1cm^3$



$26m^2$ takes up
400L of CO_2
from one person/24 hrs

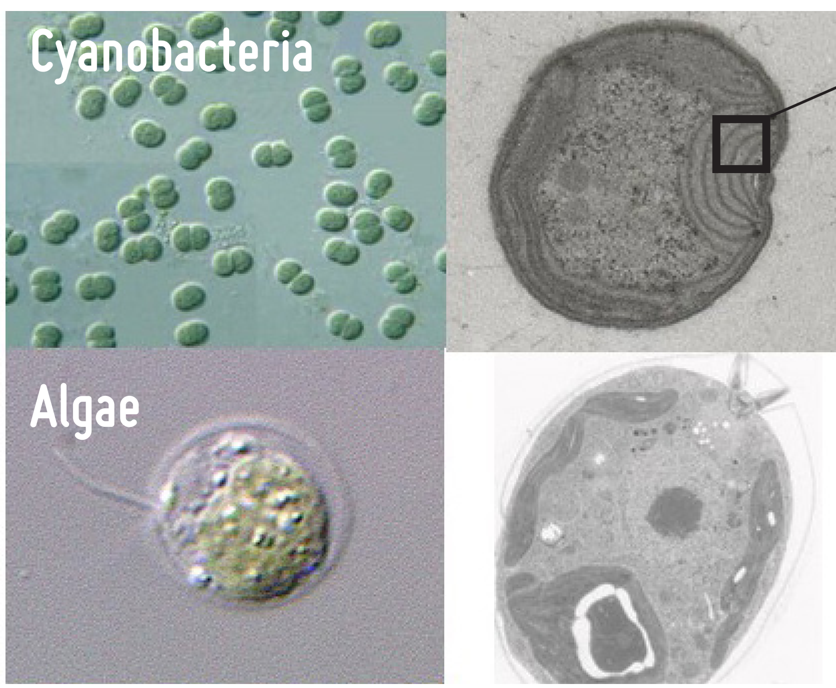


Bioprocess: electrons from photo-biosynthesis

$$H_2O + CO_2 \xrightarrow{\text{Light}} \text{Biomass} + O_2 + e^-$$

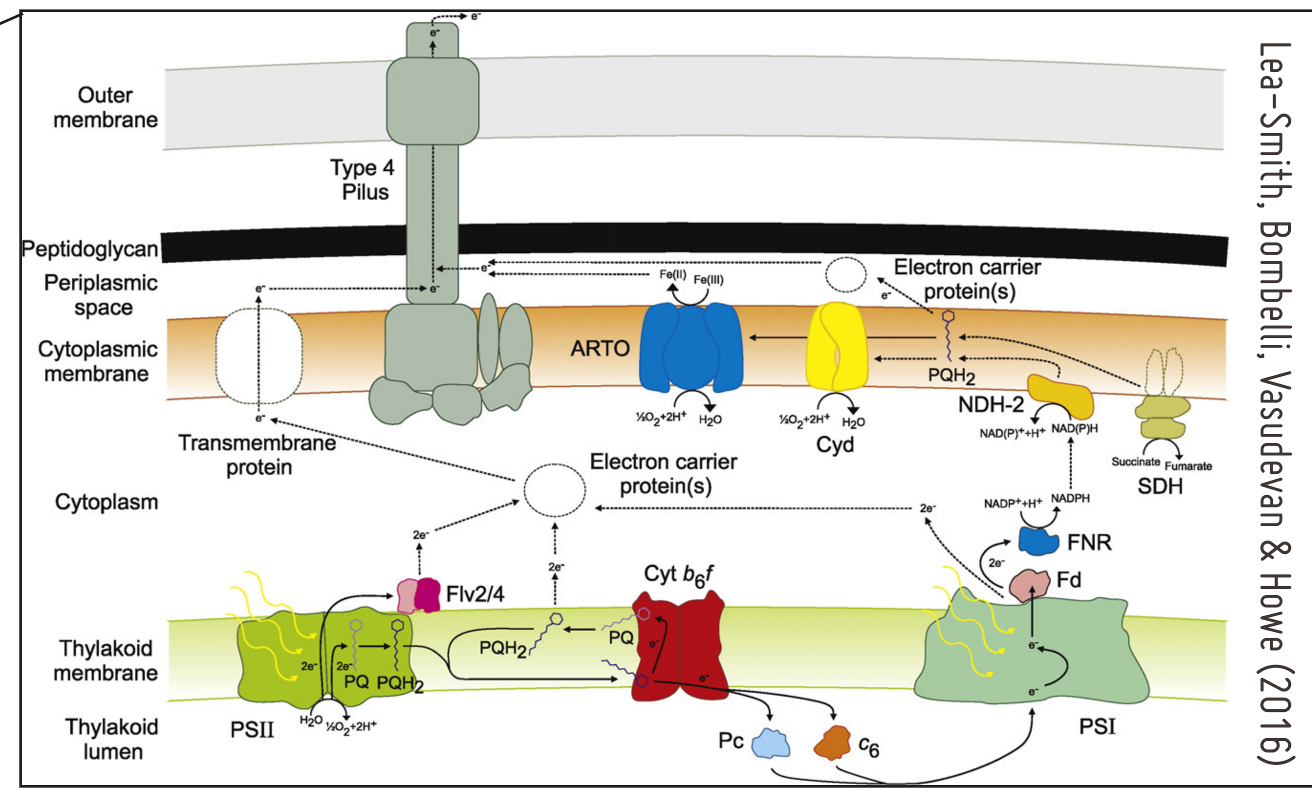
Equation of photosynthesis

Images from Internet



Light microscopy

Electron microscopy



Lea-Smith, Bombelli, Vasudevan & Howe (2016)

Diagram of possible electron transport routes between the membranes and the exterior (electrons in black lines)

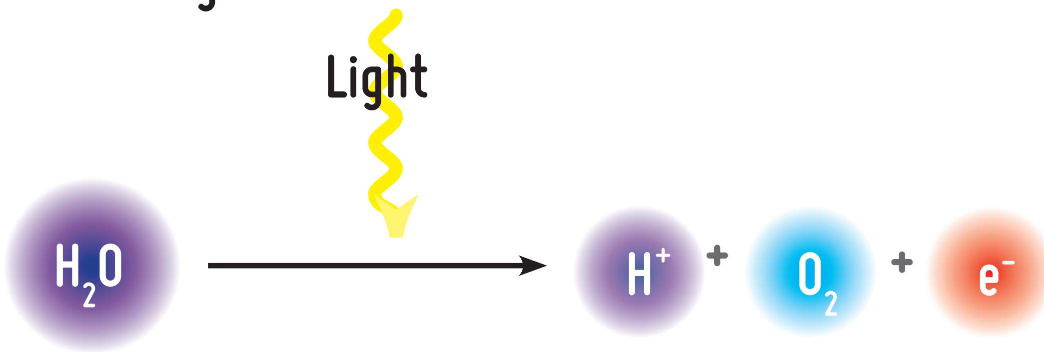
Lea-Smith, Bombelli, Vasudevan & Howe, 2016. Photosynthetic, respiratory and extracellular electron transport , pathways in cyanobacteria. *Biochimica et Biophysica Acta – Bioenergetics*, 1857(3), pp.247–255.

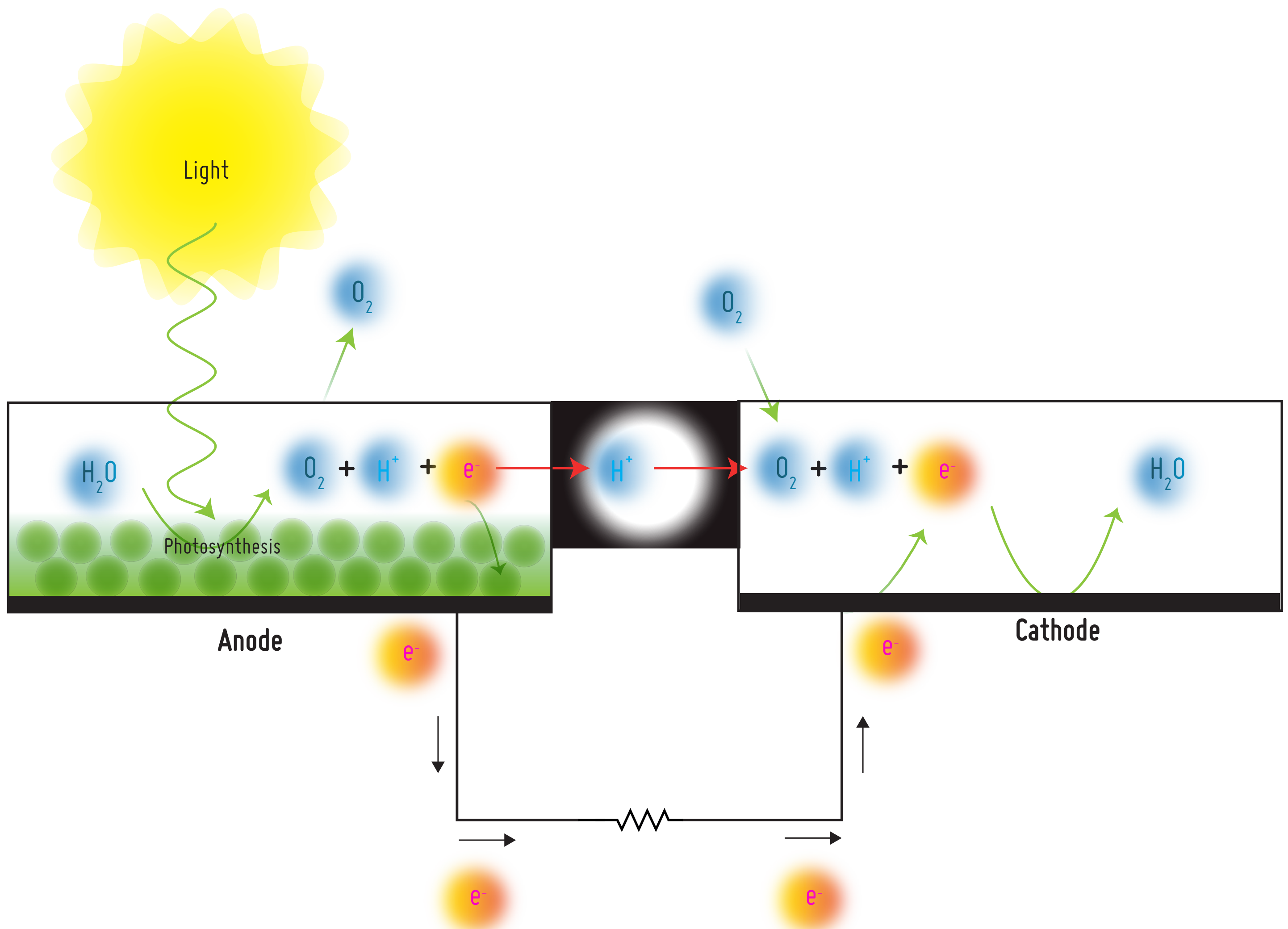
"In a very simple way, a biophotovoltaic is a biological solar panel. So it is a biological solar panel that operates based on biological materials, and those biological materials could be plants as well as algae. Electrons are essential for any living organisms. And this is true for animals as well as plants. So what we do with biophotovoltaics is that we build a way to channel those electrons outside the cell. The fact that in photosynthesis you are building up the bricks, the fundamental bricks for new life. And the initial fundamental bricks are carbs (carbohydrates). To do so, you need to combine a carbon dioxide with a proton and electrons. Then we go back to the concept of electrons. So for photosynthesis, electrons are essentials. In biophotovoltaics, actually we don't go as far as to build up 'products'. The only thing that we aim is to get electrons from water."

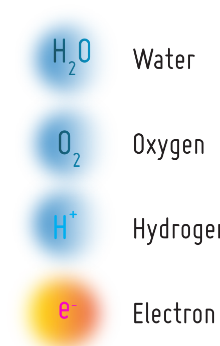
Dr Paolo Bombelli (Prof Chris Howe group, University of Cambridge)

Biophotovoltaic technology and science

The challenge is how to harvest 'free' electrons







Schematic of a typical planar BPV system

Proof of concept – digitally printable BPV cell

All experiments carried out in collaboration wtih Dr. Andrea Fantuzzi and Nixon Group at the Biochemistry lab. Imperial College London

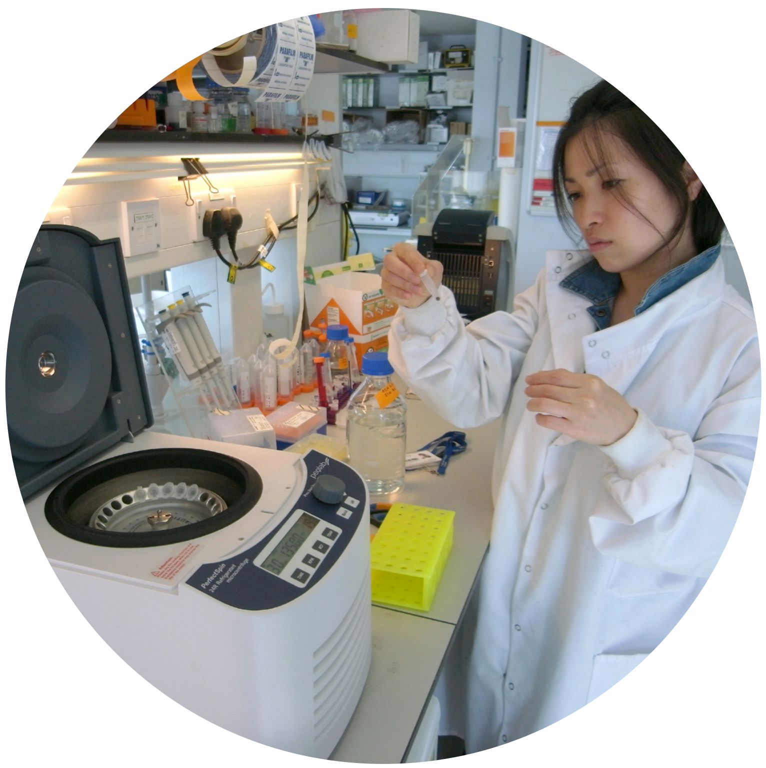
Proof of concept – digitally printable BPV cell (bioelectrode)

All experiments carried out in collaboration wtih Dr. Paolo Bombelli (University of Cambridge) and Nixon Group (Imperial College London)

Collaborative Process

Sir Ernst Chain Building, Life Sciences, Imperial College London

Designer in Residence



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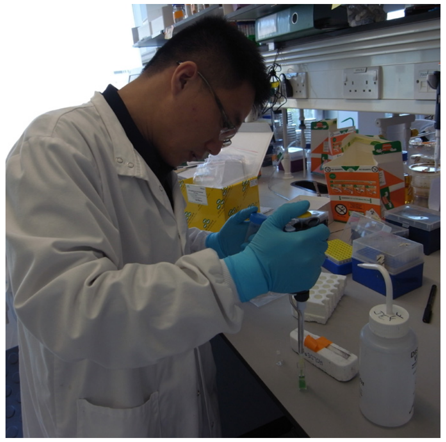
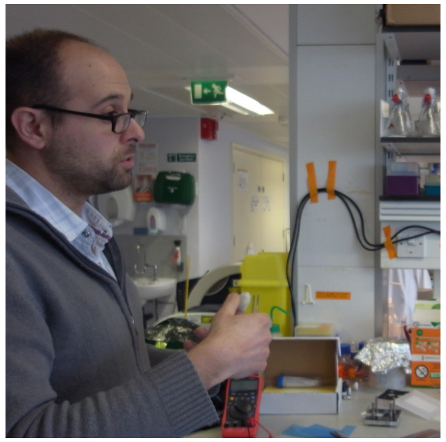
Main collaborator scientists





Interview question

What interested the scientists to collaborate?

Prof Peter Nixon
– Biochemist

“

First of all, I did know what a designer did and so I was intrigued about what designers did and what designers could offer to scientist researchers. I first met Marin at a meeting with Nigel Brandon, who was the head of the Energy Futures Lab (Imperial), and I came back from the meeting, feeling very impressed because first of all, she was very passionate about the subject area, I knew that I had to help with her studies.

”

Interview question

What interested the scientists to collaborate?

Dr Andrea Fantuzzi
– Electrobiochemist

“ The first step was a scientific curiosity. I had an interest in how cells behave once they were printed and how they behaved on paper. And we did an initial fluorescence measurements. This was the first step that hooked me into a kind of project. The second time came a more application-based, more applicative aspect of the project. I have a multidisciplinary background. I worked for a very long time, developing biosensors in an industrial setting. So it was only natural for me to think about when possible applications to the science I do. We thought together about what kind of application these printed systems could have. One of these possibilities was developing solar batteries and potentially biosensors. This is how it developed my interests in the project.. ”

Interview question

What made it a successful (two-way) collaboration?

Prof Peter Nixon
– Biochemist

"

What made it a good collaboration that made it go in a seamless way was her work in a laboratory setting and to become part of the research team. This meant that she became familiar to the lab members and a friend to all of us and also that she learnt the common language that we could also converse in — that of a scientific terminology and scientific language. So as the time passed, we were about to communicate easily and freely about her project and process. In this case, Marin performed the research herself and she did the lab work and by being the lab, we could look at the results together, and there was a dialogue o a debate about where to go next in her research.

"

Interview question

What made it a successful (two-way) collaboration?

Dr Andrea Fantuzzi
– Electrobiochemist

“ I think that one important aspect is proximity. The fact that you were part of the Nixon Group allowed much closer interaction and a possibility of discussion when we had a free time, a possibility of closer relationship during the experiments. ”

Interview question

What were intersections with your scientific research?

Dr Jianfeng Yu
– Biochemist

“

I was working on my PhD research and was using a particular strain called Synechocystis PCC 6803 for photosynthetic studies. We grow that strain routinely in the lab and so we can easily produce you know, we have the capacity to provide enough material for Marin to practice her printing, and potentially we have additional knowledge to support for any trouble shootings So it was a convenient for both sides.

”

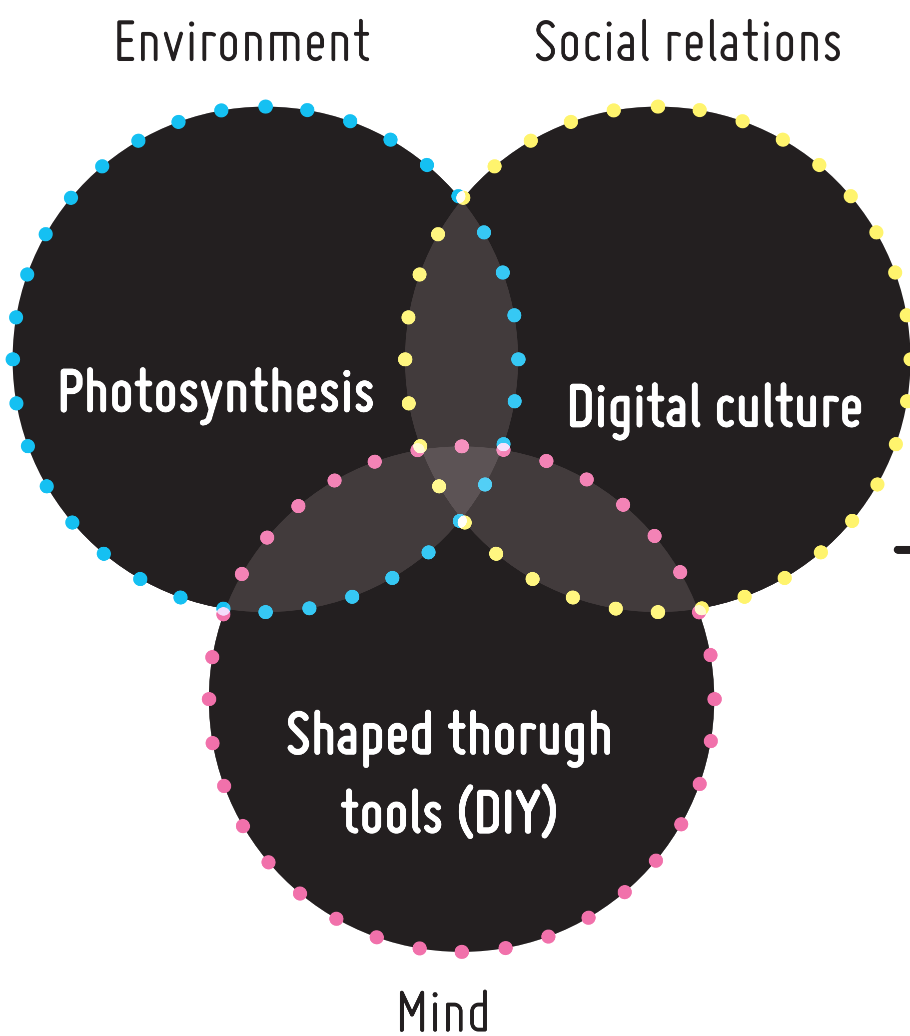
Interview question

What made it a successful (two-way) collaboration?

Dr Paolo Bombelli
– Biochemist

"Being able to deliver algae in a specific position above an electro-conductive surface is to give a scientist an additional tool of investigation. We can better understand the process of electron transport, and as I said before in electron transport, exporting electrons is perhaps is one of the main bottlenecks of this technology. So printing cells could actually help to sort out one of the biggest bottlenecks of this technology. When we are thinking to scale up, if we are able to print something, the scaling-up is definitely, definitely more possible. So, whether larger applications are not jet achieved, able print algae as well as the non-biological part of the system could actually pave the way for practical applications."

Being physically embedded encouraged a deep-seated dialogue of material thinking between the designer and scientists. This dialogic process occurred on a day-to-day basis and amplified serendipitous discoveries through social interactions within the realm of the particular environment. Such serendipity catalysed genuine intersections between design and science. I think that the embeddedness brings together the social, mental and environmental ecologies of the place and creates an intense ecosophical place to allow a two-way interdisciplinary collaboration to flourish.
Marin Sawa (2015, p140)



Filter
[Oxygenation, carbon sequestration, bioremediation]
Currently in R&D

Renewable bio-energy
[Biofuels, hydrogen and bioelectricity]
Currently in R&D

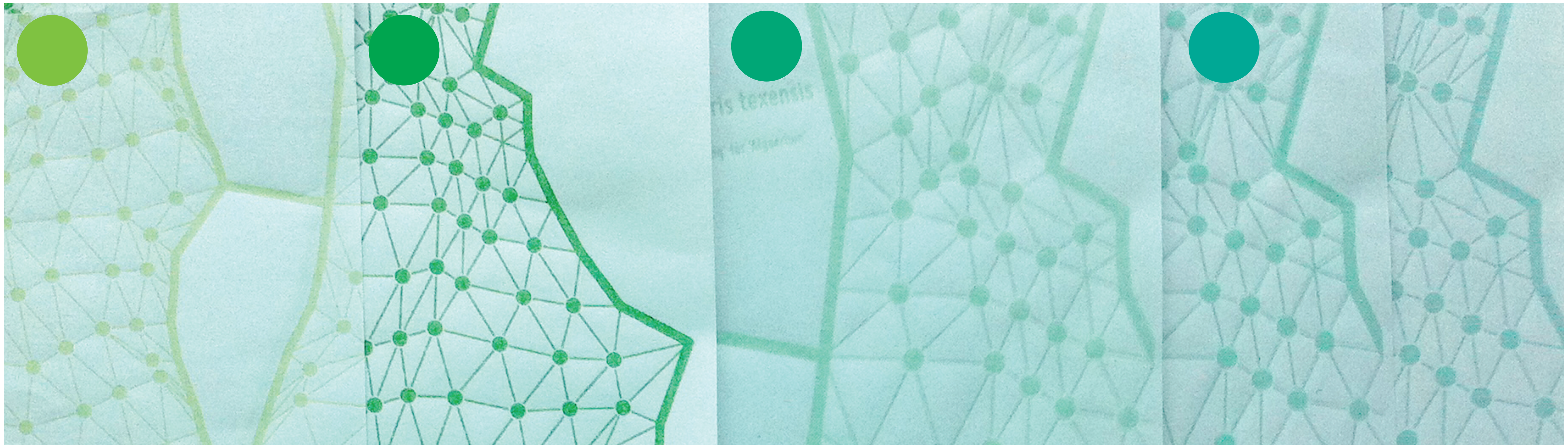
Health food
[Vitamins, proteins]
Available in industry

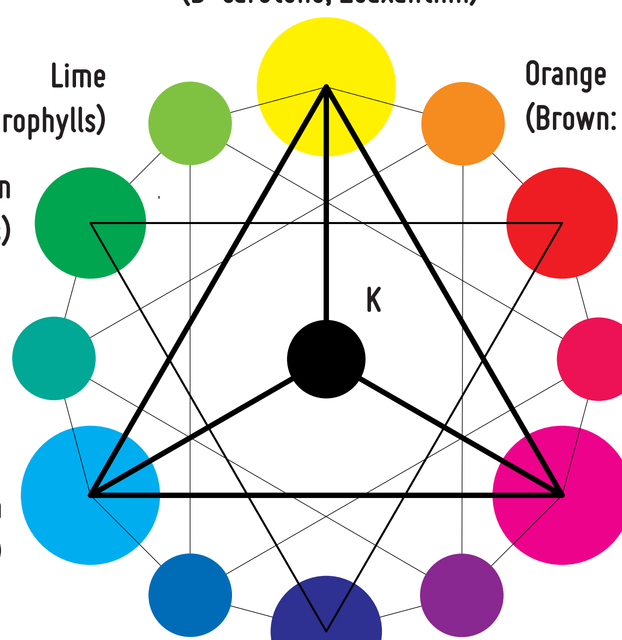
Lime
Chlorella sorokiniana

Green
Thermococcus elongartus

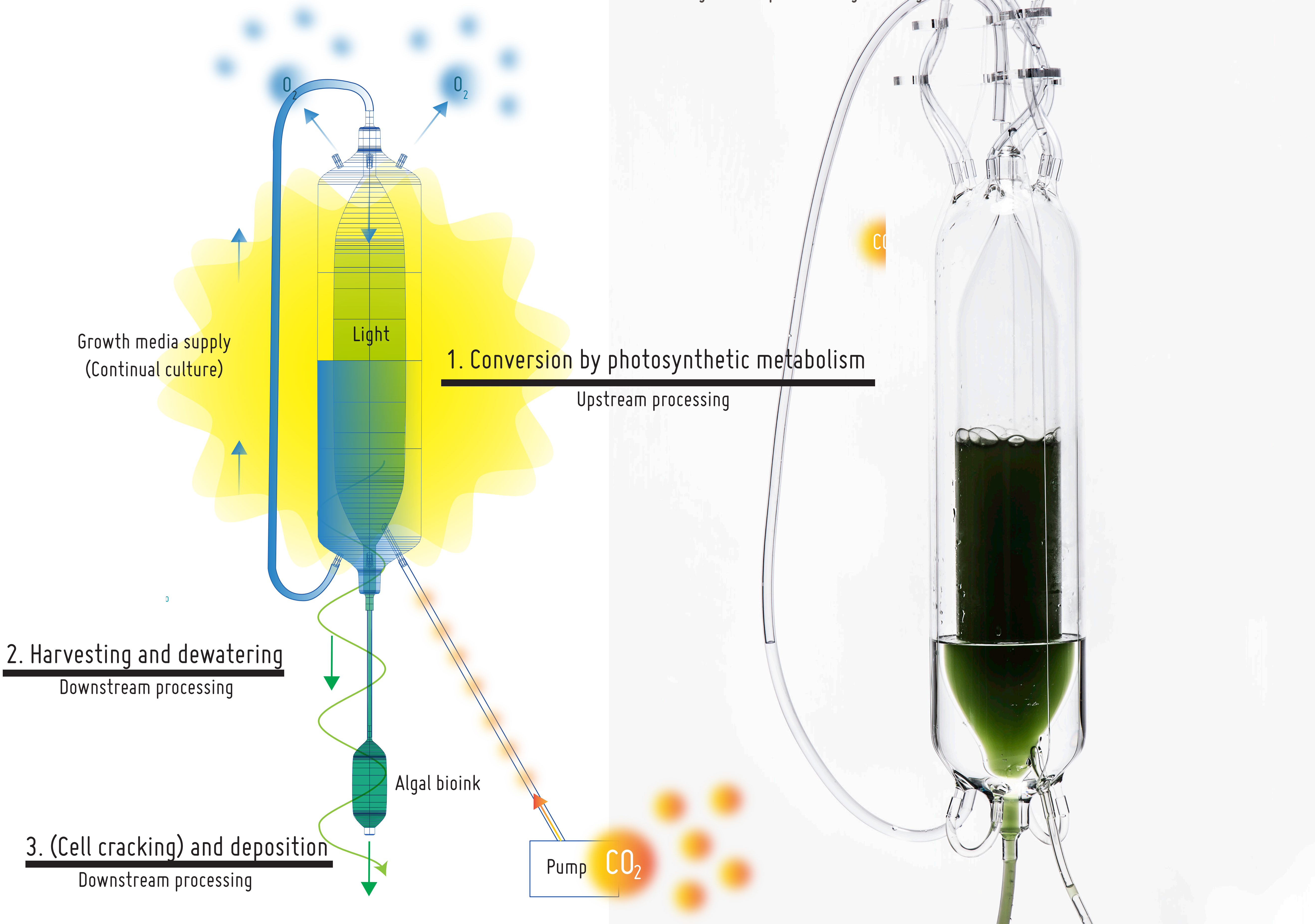
Green – Aqua
Neochloris texensis

Aqua
Synechocystis sp.



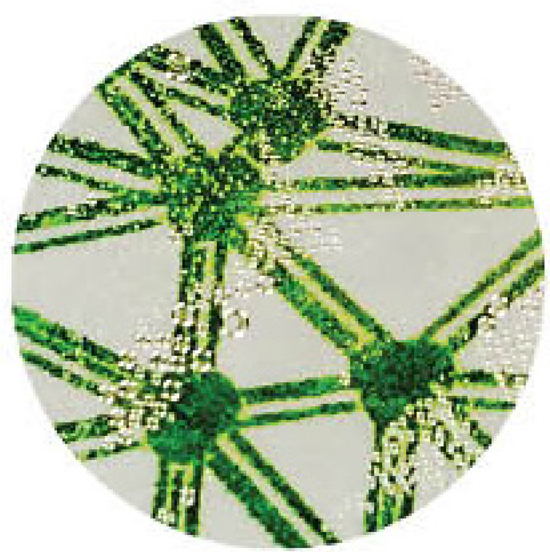
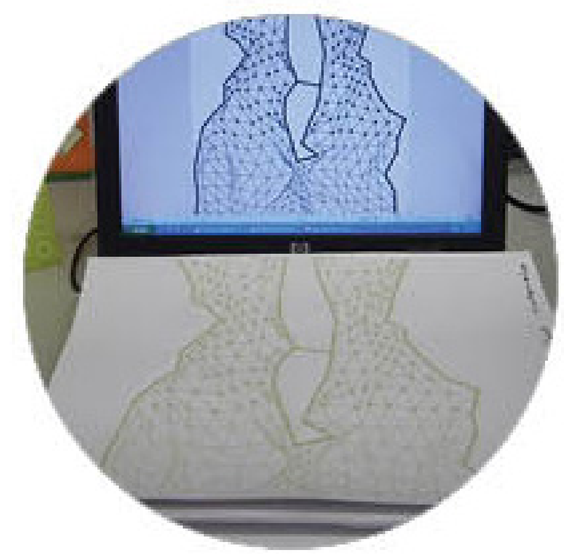


Bioprocessing overview of Algaerium Bioprinter





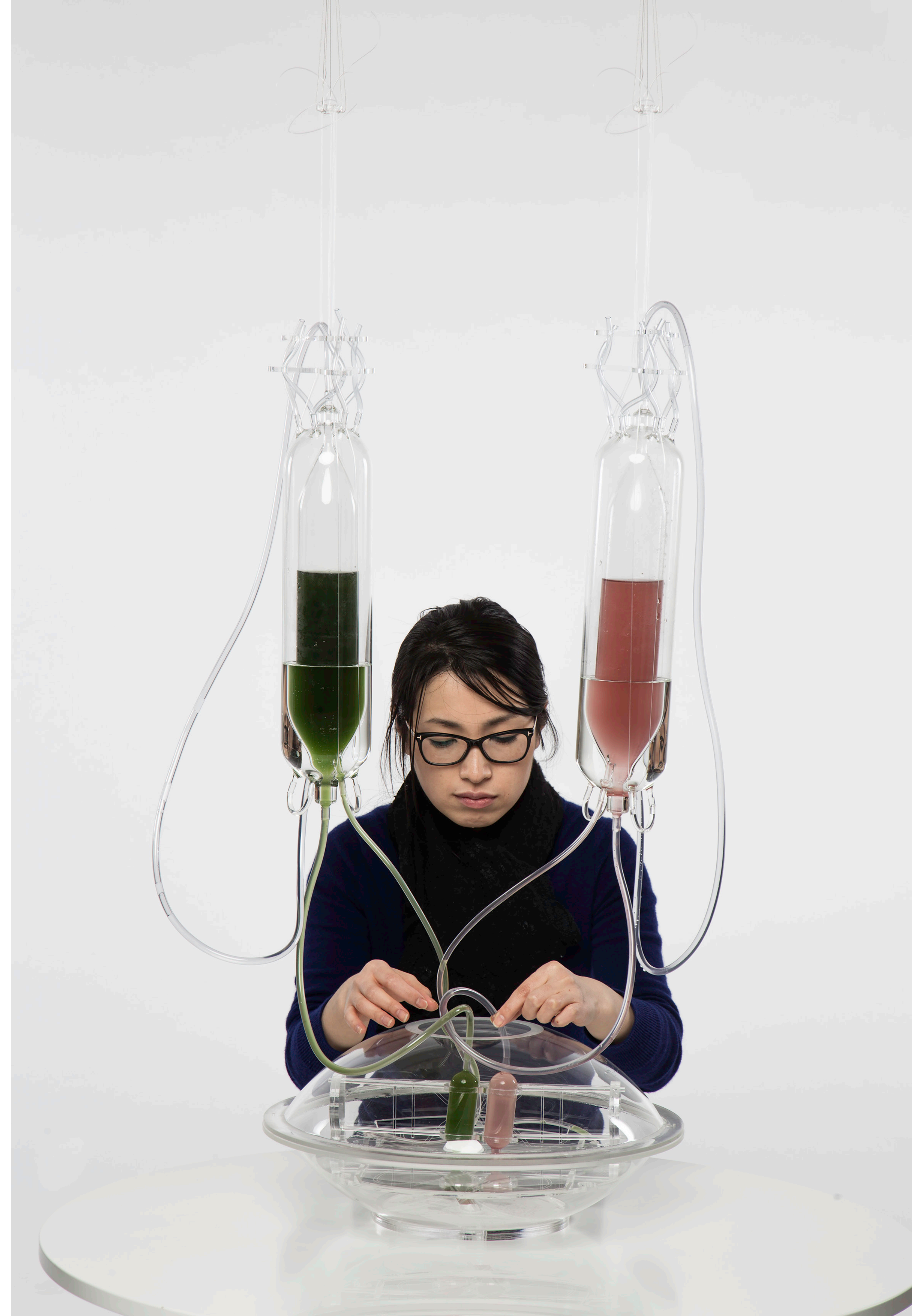
The culture centre → The lab → The industry

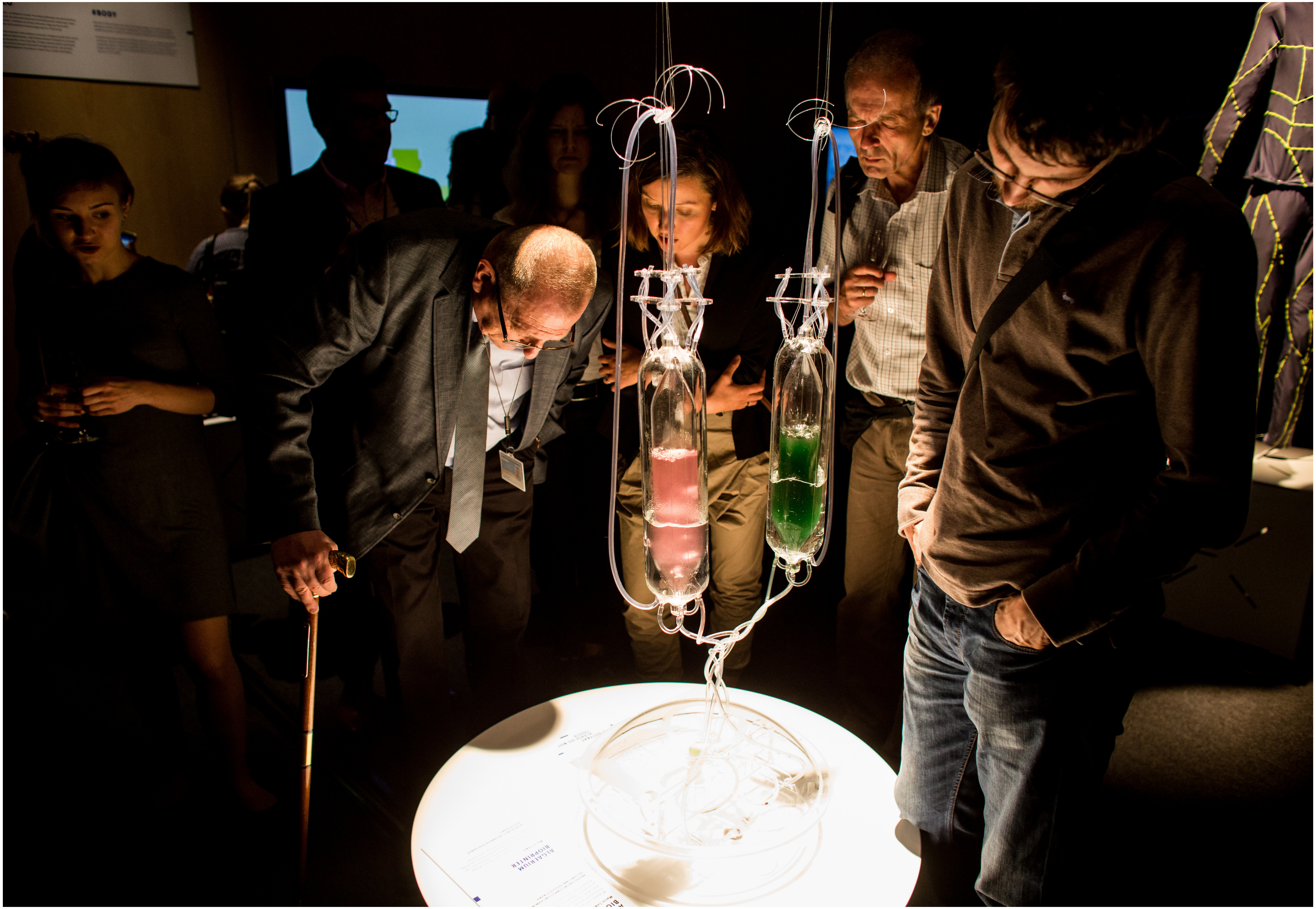
Flexibility
(End-users, customisation)

Algaerium Bioprinter towards ‘utilitarian consumption’

‘En Vie/Alive’, Foundation EDF, Paris, 2013



© Marin Sawa Algaerium Bioprinter installation, Algae in Space, Science Museum, 15 Dec 2016 Credit: photography by Imperial College London



Algaerium Bioprinter installation in a public museum space at the Anthropocene exhibition, Warsaw, 2015.
© Marin Sawa   Credit: photography by the Copernicus Science Centre

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Second supervisor: Prof Peter Nixon (Imperial College London)

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Further collaboration with
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Prof Alexander Ruban and Dr Petra Ungerer (Queen Mary University of London)
Prof Conrad Mullineaux and Dr Dennis Nürnberg (Queen Mary University of London)

Thank you.
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