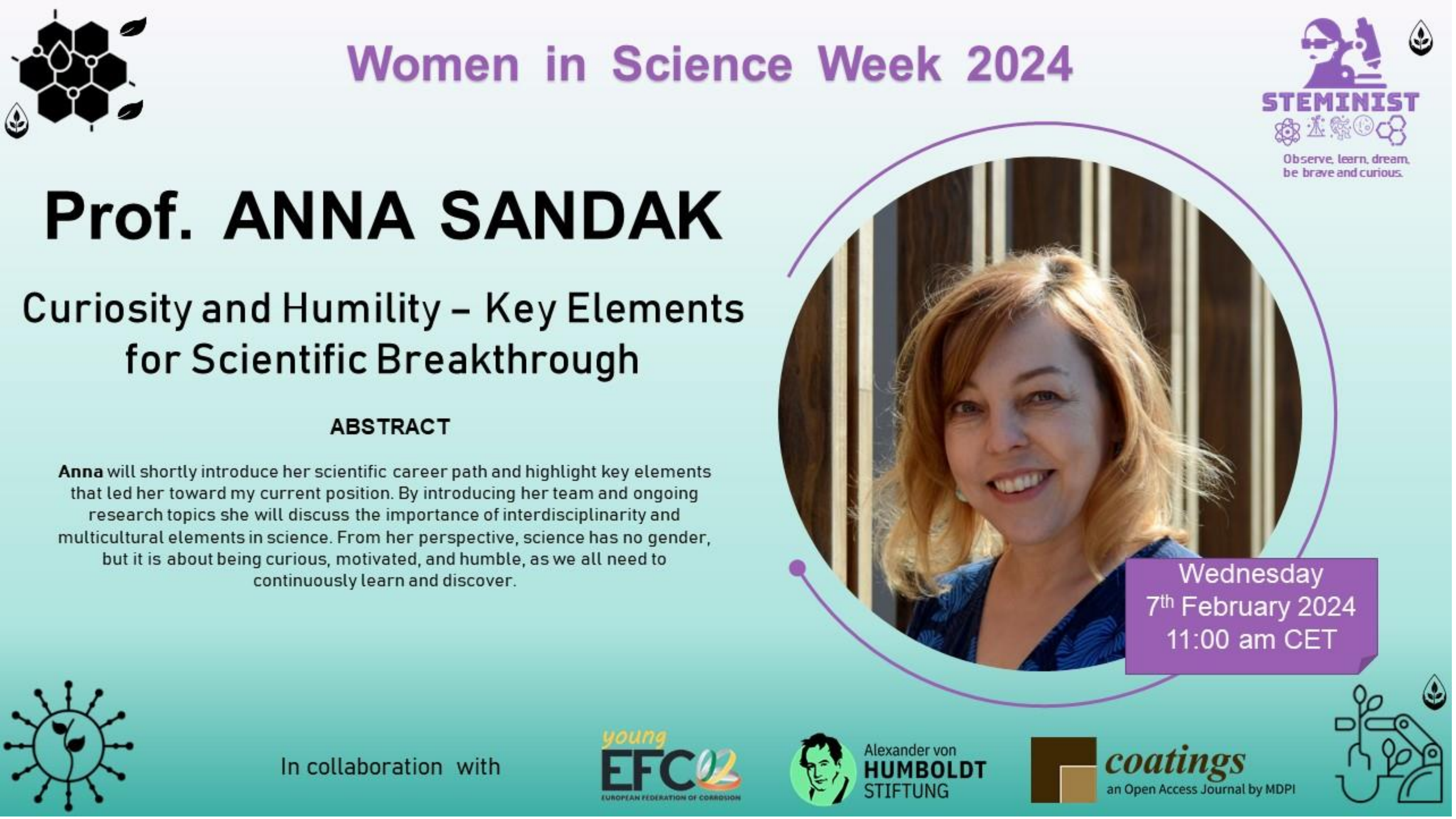
WOMEN, MINORITIES & STEMINISTS IN SCIENCE WEEK 2025- SPACE EXPLORATION



Message #1

Make plans but be flexible and open to opportunities. Be bold

InnoRenew CoE

Livade 6, 6310 Izola/Isola, Slovenia, T: +386 40 282 944, E: coe@innorenew.eu, www.innorenew.eu

Resilience Beyond Earth: Opportunities for Engineered Living Materials in Space

with contribution of Anja Černoša, Ana Gubenšek, Wojciech Pajerski, Karen Butina Ogorelec, Faksawat Poohphajai, Aleksandar Tošić, Valentina Hribljan and Sasikala Perumal

Anna Sandak, PhD
Deputy Director and Head of Materials Department, InnoRenew CoE
anna.sandak@innorenew.eu
Associate prof. FAMNIT & IAM University of Primorska

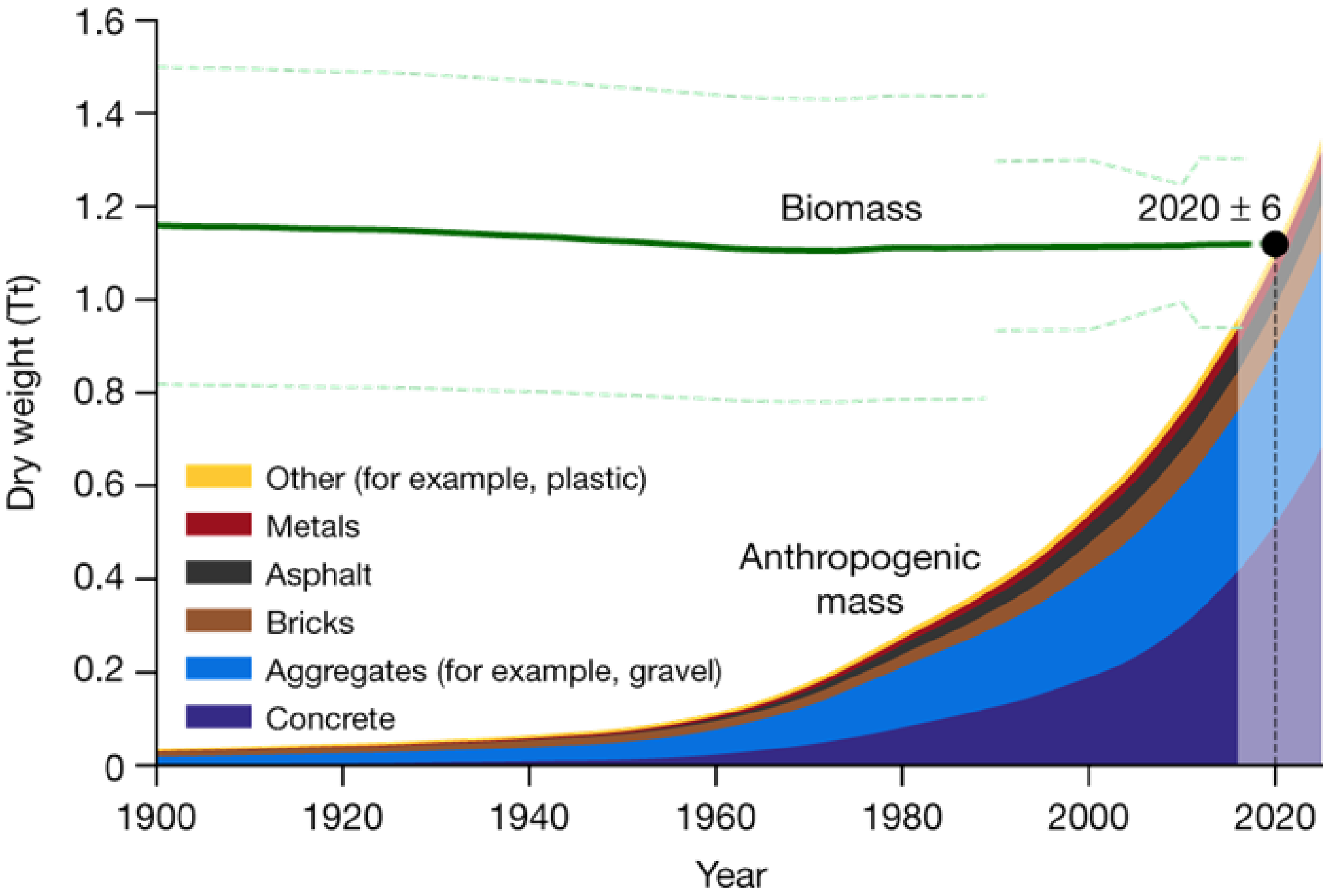
Outline

- What are the challenges of (space) construction?
- Do we need alternative building materials?
- What are Engineered Living Materials (ELMs)?
- Why space need ELMs?
- Our research related to ELMs
- Mission Possible: Project Genesis
- Beyond space: how space innovation transforms earthly materials?

Horizon 2020 Framework Programme of the European Union; H2020 WIDESPREAD-2-Teaming: #739574

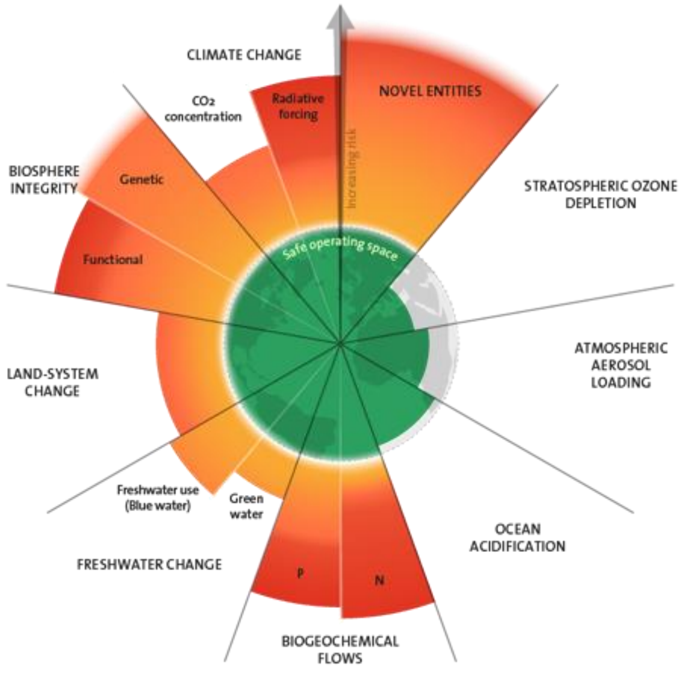
14 million tons of plastic end up in oceans each year

Planet boundaries



Elhacham, E., Ben-Uri, L., Grozovski, J. *et al.* Global human-made mass exceeds all living biomass. *Nature* **588**, 442–444 (2020)

2023



9 boundaries assessed, 6 crossed

Credit: Azote for Stockholm Resilience Centre, Stockholm University. Based on Richardson et al. 2023, Steffen et al. 2015, and Rockström et al. 2009


EXTREME


HUMPS


Do we need a new perspective on sustainability?

3.6 billion years of nature versus 300.000 years of human

assembly

complexity

volume

extreme

linear

disposal

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grow

simplicity

shape

ambient

circular

decay

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Biological systems

multifunctional

optimized

Bioinspired innovations

things that are created in nature can inform the **development of new materials**;

the natural organization can inform **potential shapes** for man-made materials;

the way organisms perceive can inspire **a new generation of sensors**;

the way animals and plants move in their environment can inform **advances in mechanics and kinetics;**

the way living organisms interact can inspire **new ways of communication**,

the way living organisms perform can inspire **man-made processes.**

Can we go beyond that?

What is our vision for materials development?

merging biology with materials science

to replace sustainability with regenerative design

ARCHI-SKIN

Design with and for nature

Inspired by nature

Informed by nature

Empower by nature

Materials in nature

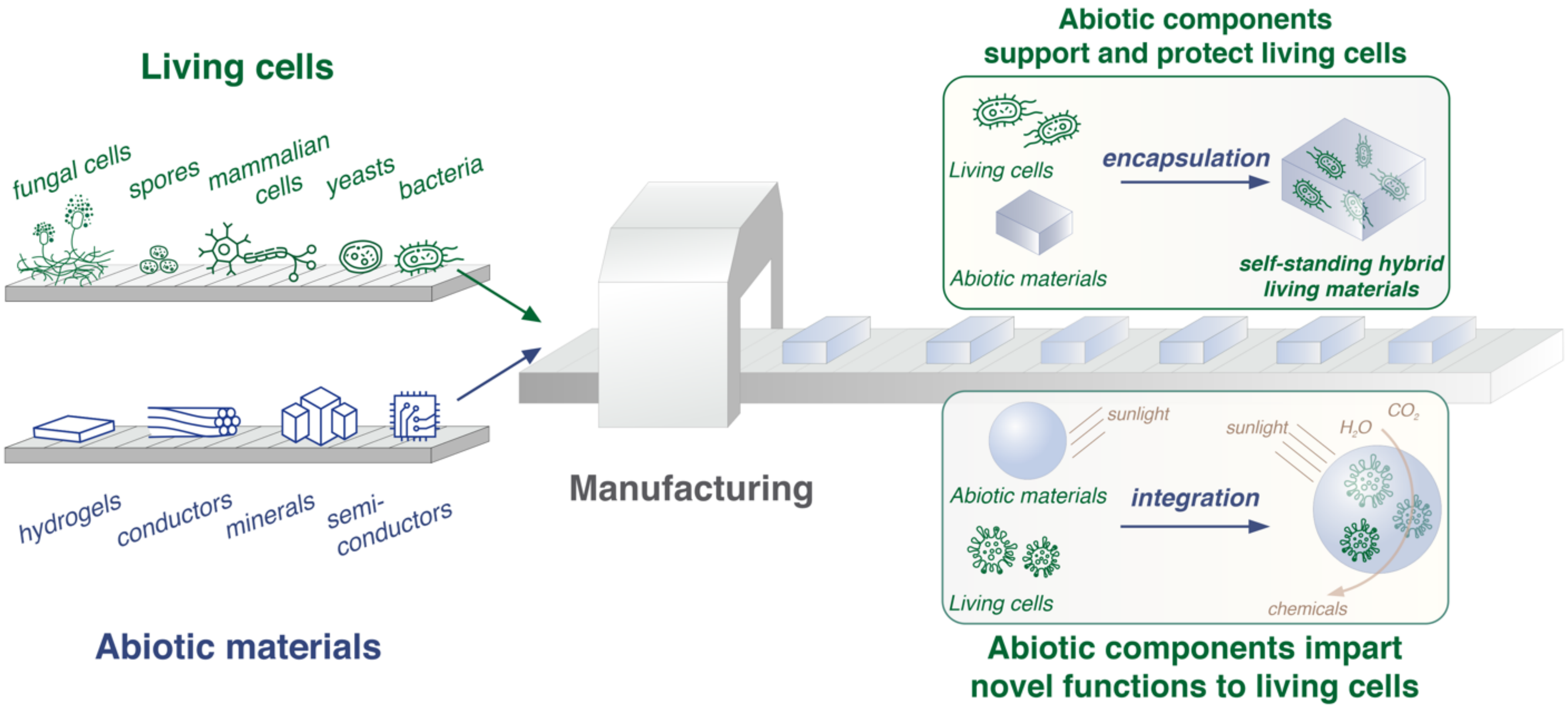
Valuable properties of materials in nature include programmability, multifunctionality, or the **'self'-properties** such as self-growth, self-adaptivity, self-assembly, or self-healing

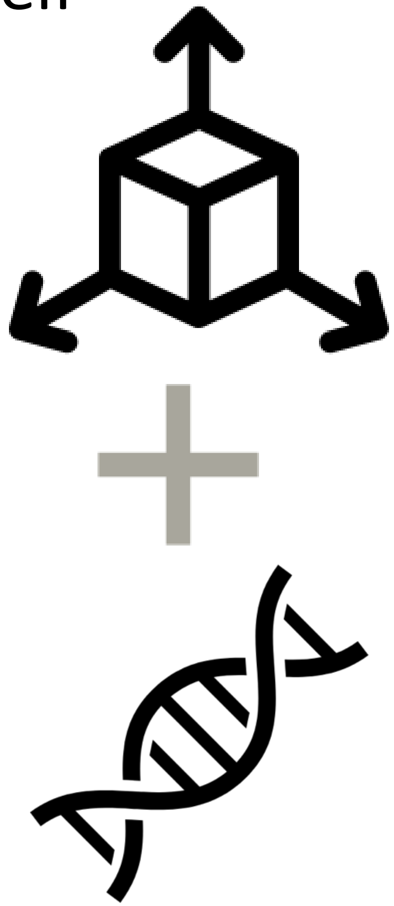
What if materials with these characteristics could be made?

Which kind of new applications will be possible?

Engineered Living Materials (ELM)

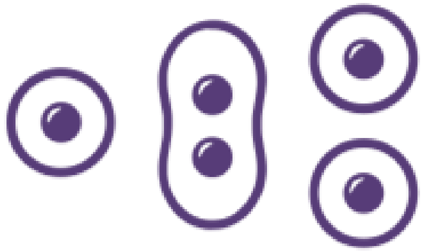
composed of living cells that form or assemble the material itself or modulate the functional performance of the material





Key features of ELMs

regeneration and self-healing



growth and adaptability

environmental responsiveness

circularity and sustainability

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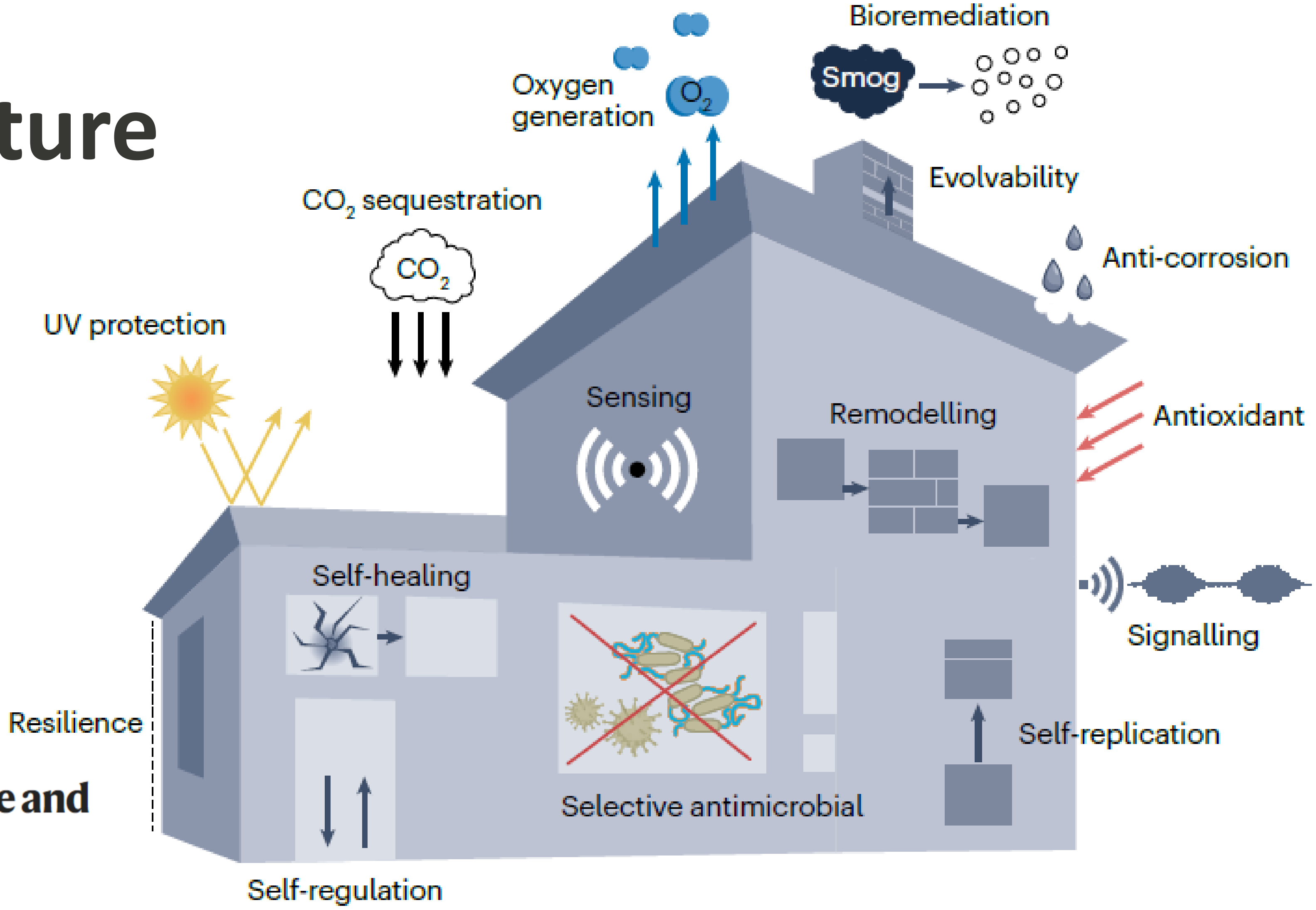
Desired properties for architecture

- remodelling
- self-regulation
- self-replication
- resilient
- sensing
- signalling
- UV protection
- anti-corrosion
- evolvability
- self-healing
- antioxidant
- selective antimicrobial
- oxygen generation
- CO_2 sequestration
- bioremediation

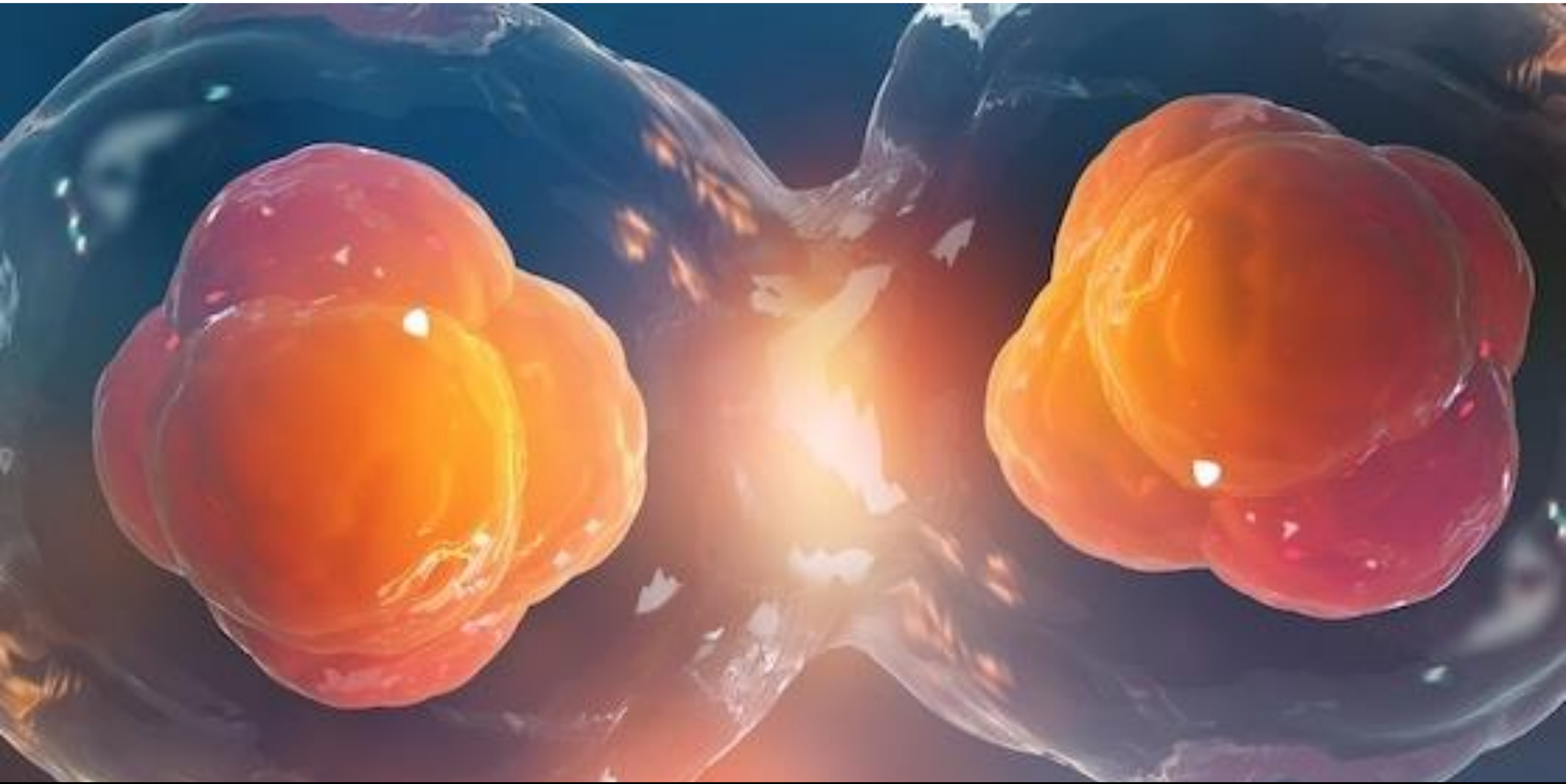
ELMs in architecture



Engineered living materials for sustainable and resilient architecture

Anna Sandak

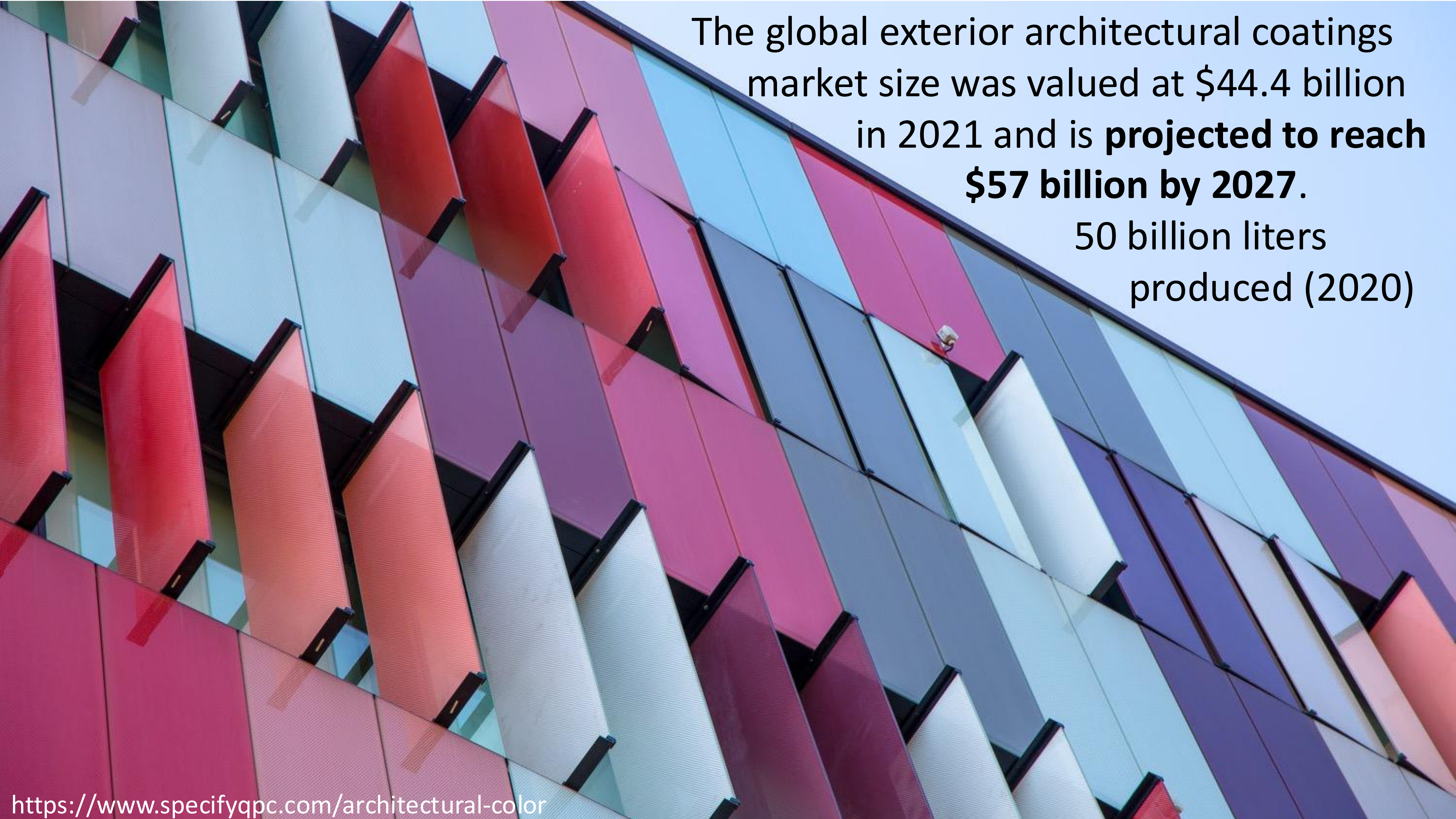
Nature Reviews Materials **8**, 357–359 (2023) | Cite this article



What if the materials in space could grow, repair themselves, and adapt to extreme environments just like living organisms?

Take or make?

Launch Vehicle	Payload cost per kg
Vanguard	$1,000,000 [21]
Space Shuttle	$54,500 [21]
Electron	$19,039 [22][23]
Ariane 5G	$9,167 [21]
Long March 3B	$4,412 [21]
Proton	$4,320 [21]
Falcon 9	$2,720 [24]



The global exterior architectural coatings market size was valued at $44.4 billion in 2021 and is **projected to reach $57 billion by 2027**.

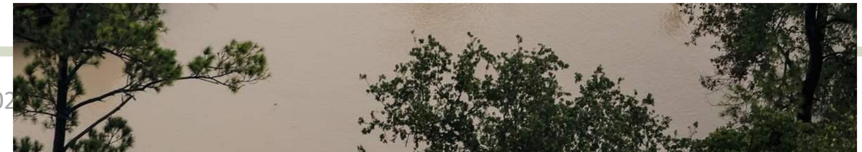
50 billion liters produced (2020)

https://www.specifyqpc.com/architectural-color





EXTREME




Weathering process

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Human approach

The conventional methods to improve coatings performance, based on adding biocides, mineral oil or synthetic chemicals make the formulation toxic and environmentally unfriendly.

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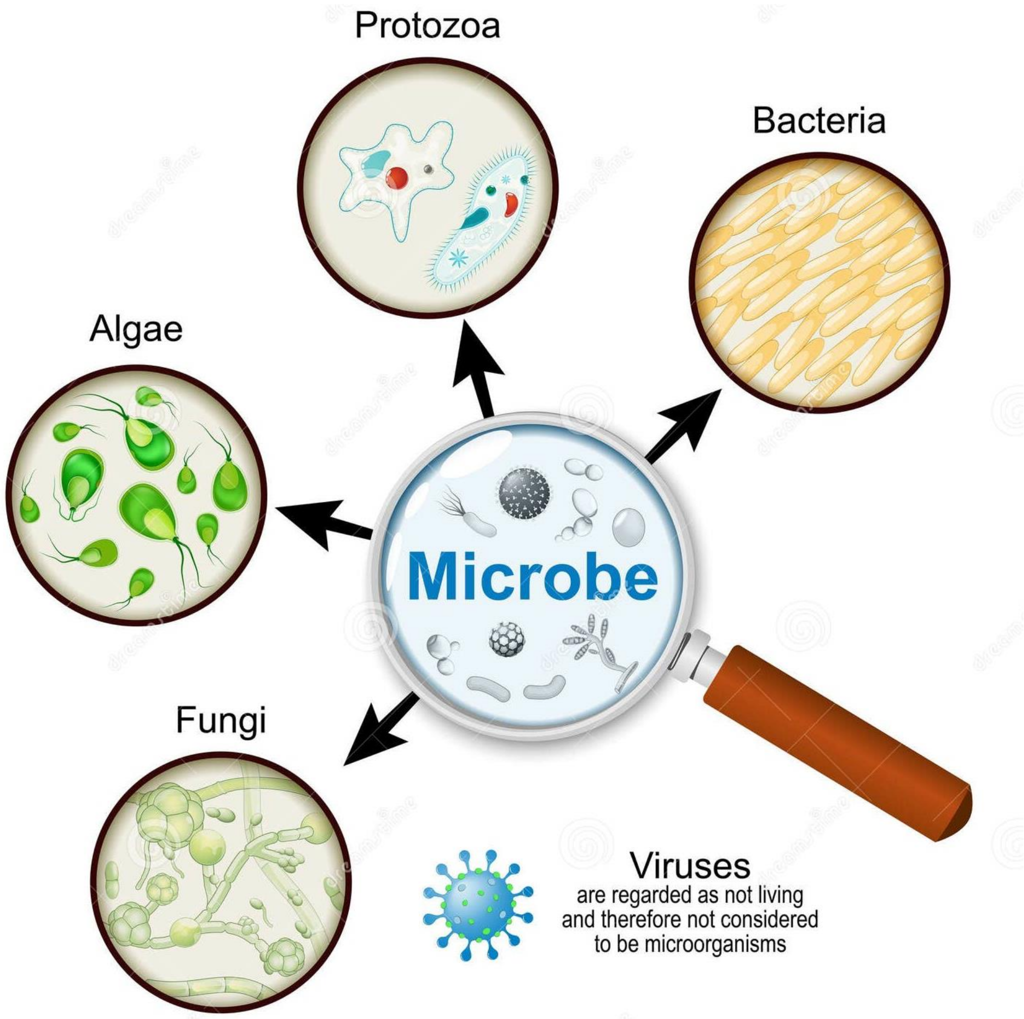
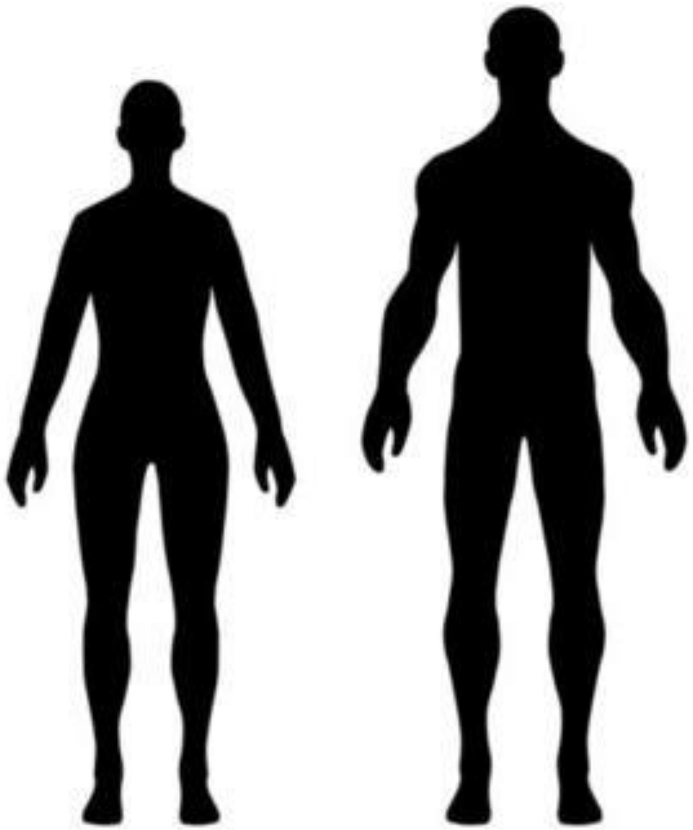
Microorganisms account for two-thirds of all life on Earth, and they are invisible to the naked eye





ID 291139333
© Designua
| Dreamstime.com

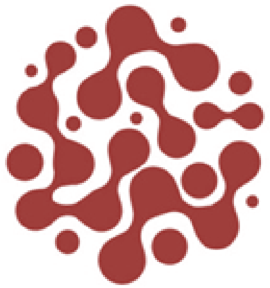
Human body contains trillions of microorganisms, outnumbering human cells by 10 to 1.

Key Concepts in Probiotic Architecture

integration of living systems

healthy ecosystems

symbiosis



microbial interaction

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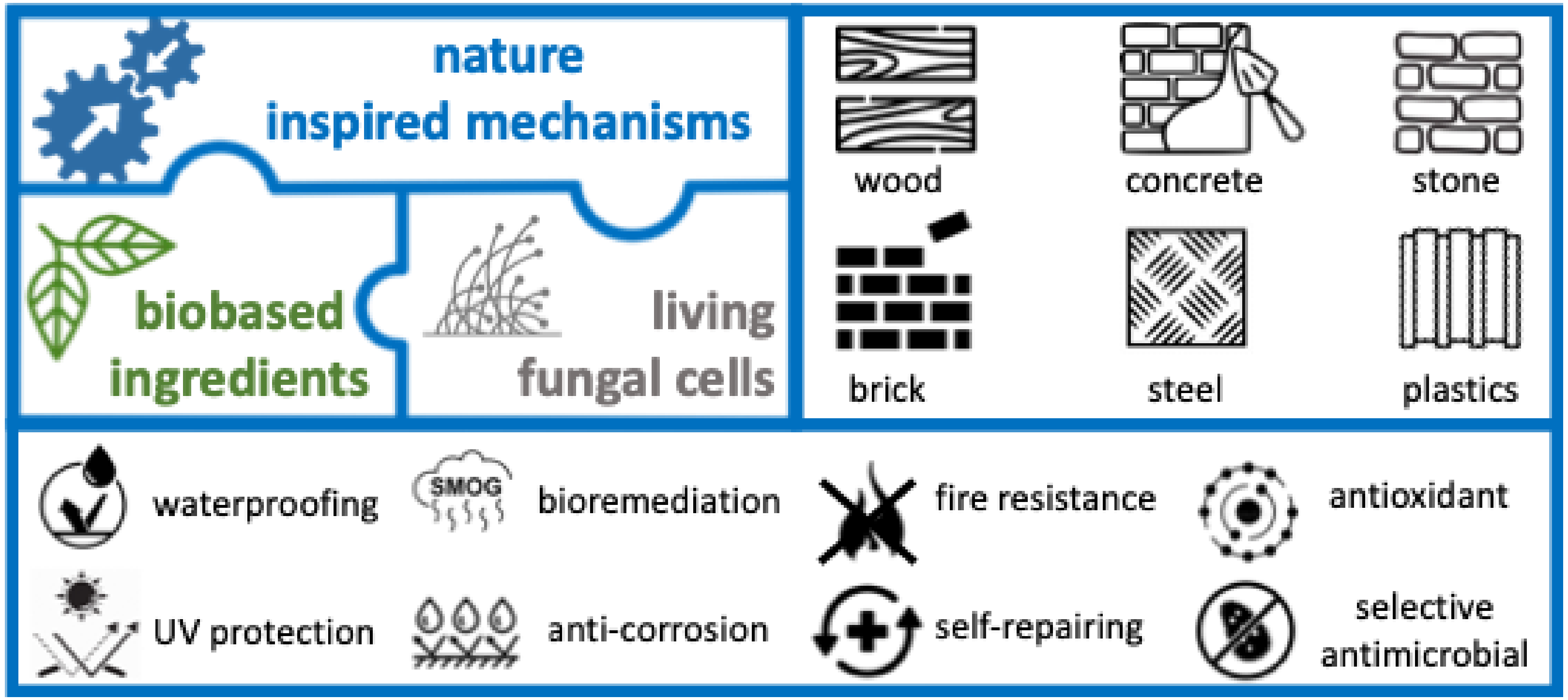
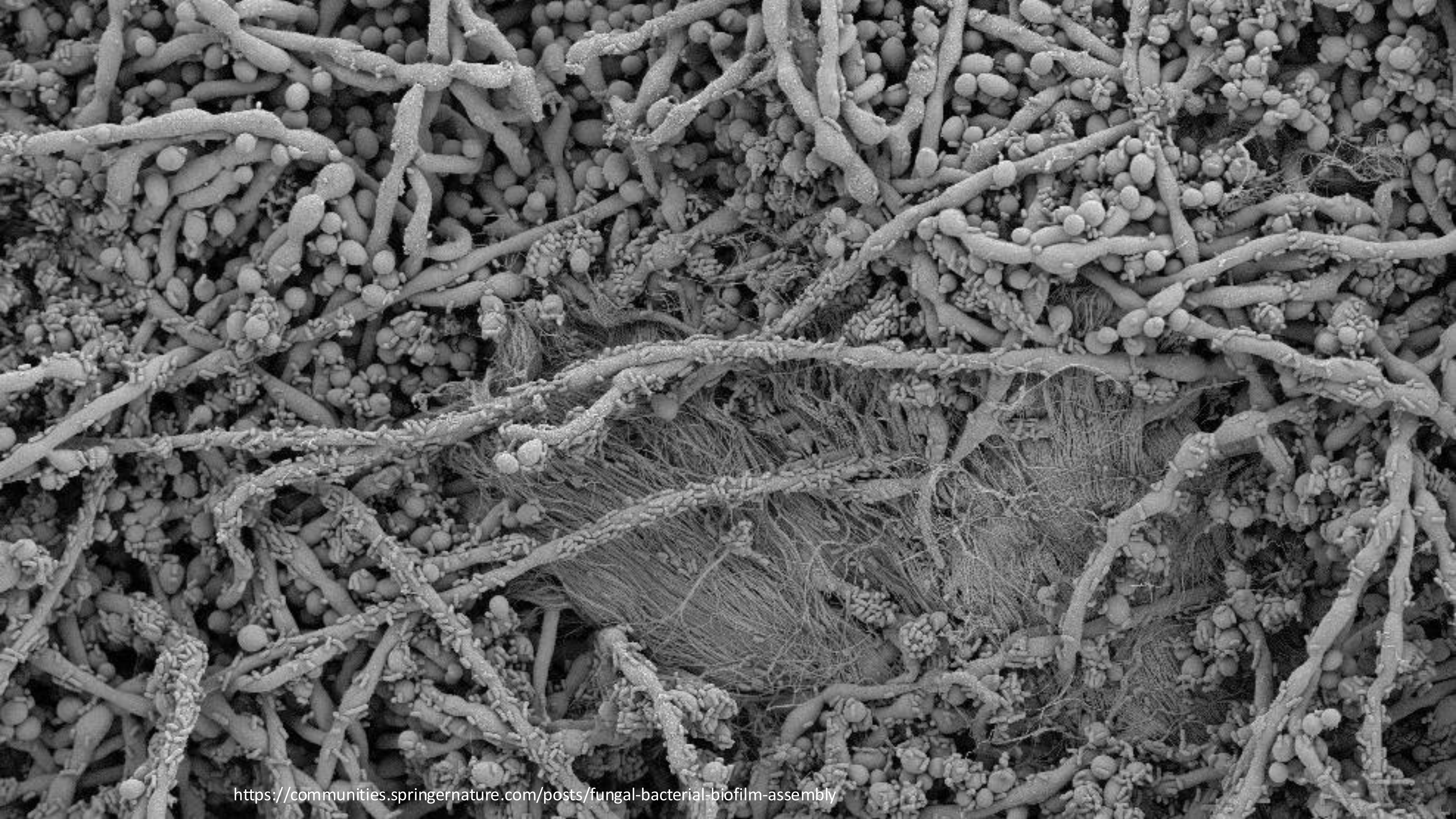
Bioinspired living skin for architecture

ARCHI-SKIN



Funded by
the European Union

European Research Council
Established by the European Commission

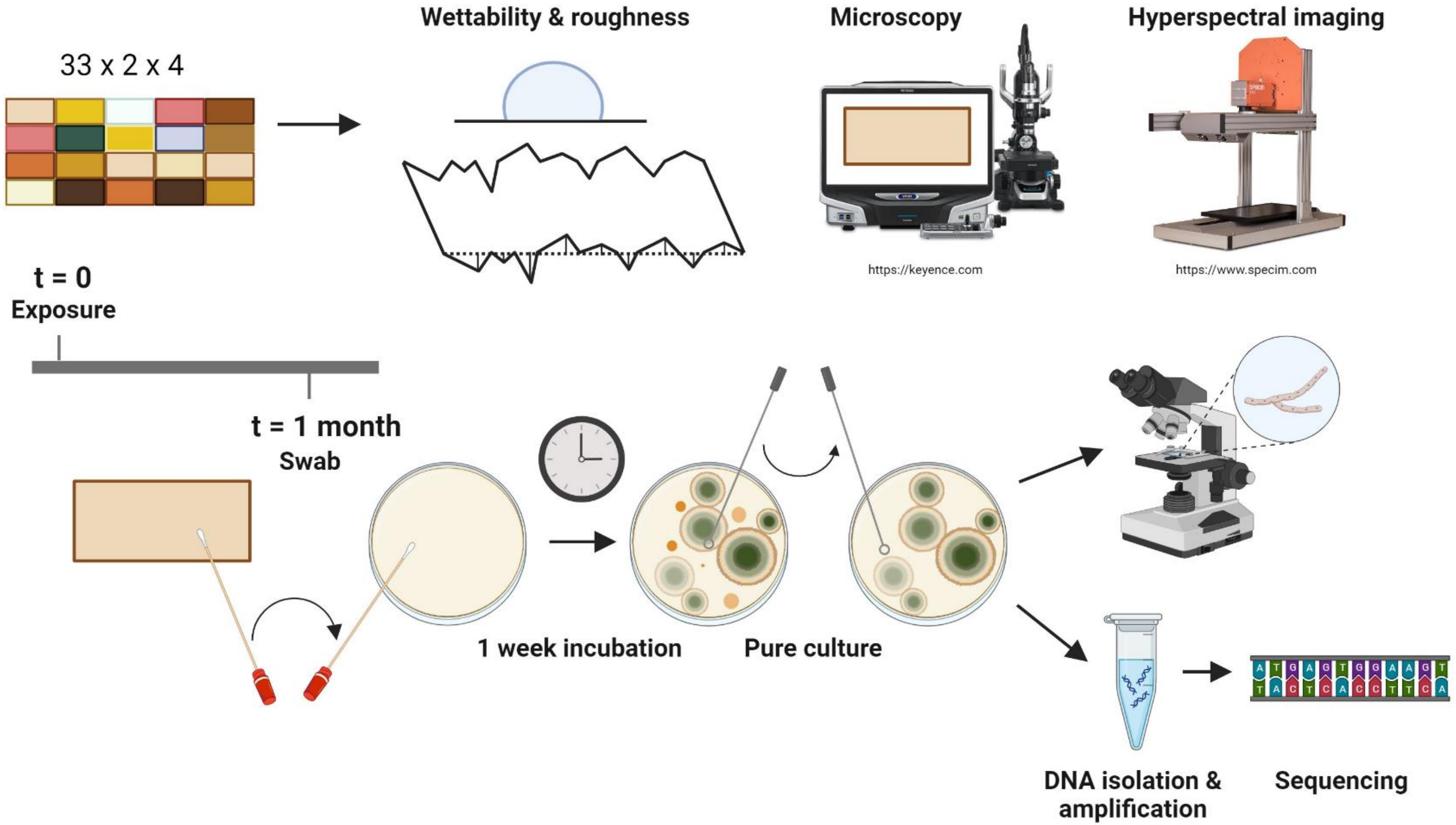


https://communities.springernature.com/posts/fungal-bacterial-biofilm-assembly

Fungi

120,000 fungal species identified (with 1.5 million estimated)

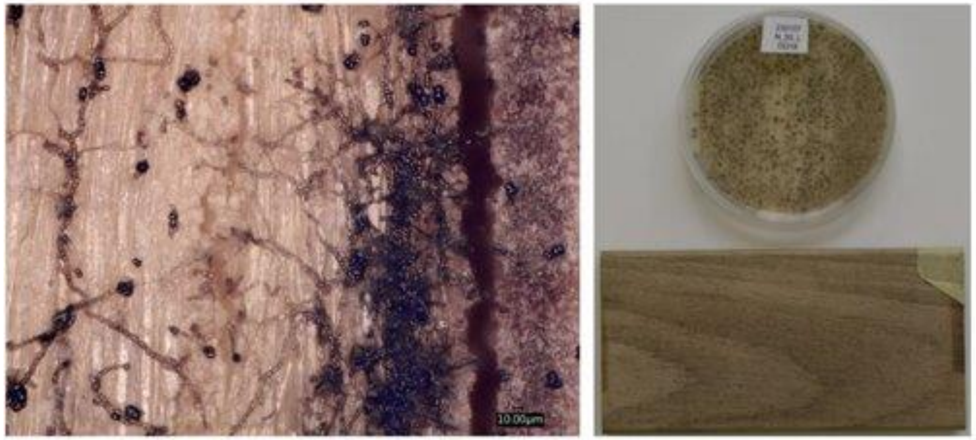
Local microbiome & bioreceptivity of ≠ materials


33 x 2 x 4
Wettability & roughness
Microscopy
Hyperspectral imaging
https://keyence.com
https://www.specim.com
t = 0
Exposure
t = 1 month
Swab
1 week incubation
Pure culture
DNA isolation & amplification
Sequencing
A T G A G T G G A A G T
T A C T C A C C T T C A

Multi-sensor characterization

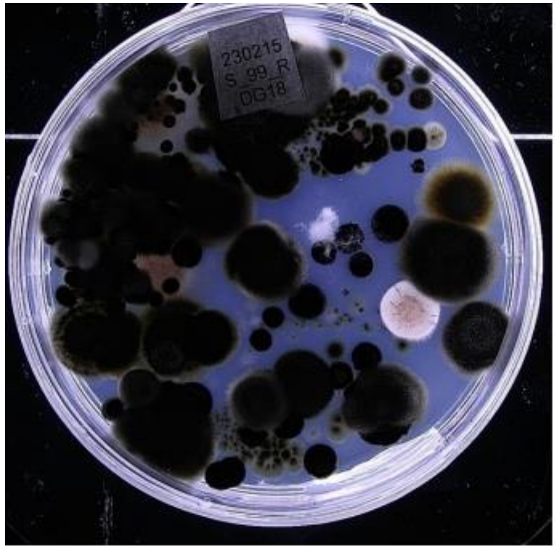
Sample: 043
Tree: Beech
Group: Natural

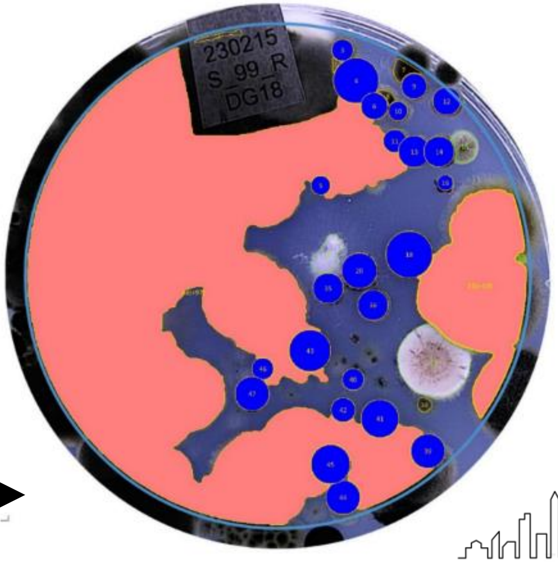
Sample: 050
Tree: Beech
Group: Chemically modified, acetylated



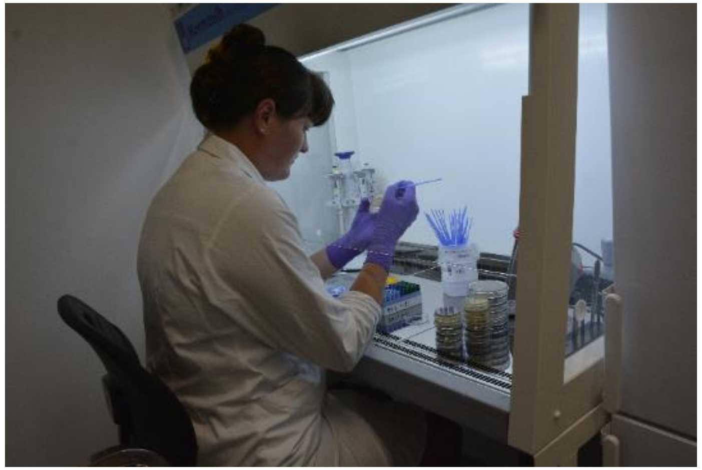
digital optical microscope

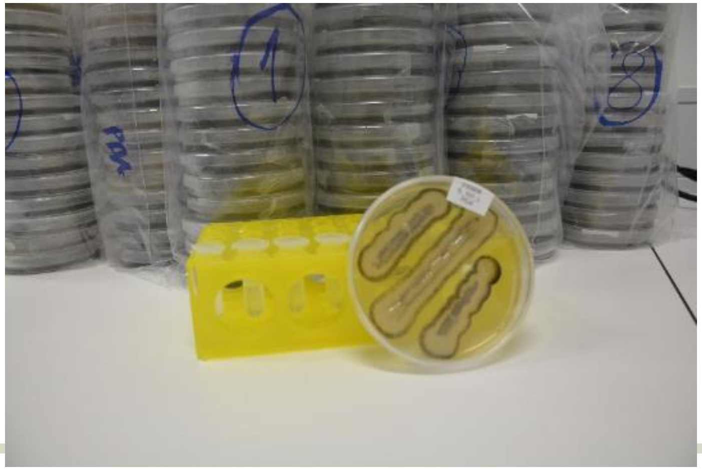
conventional colony counting

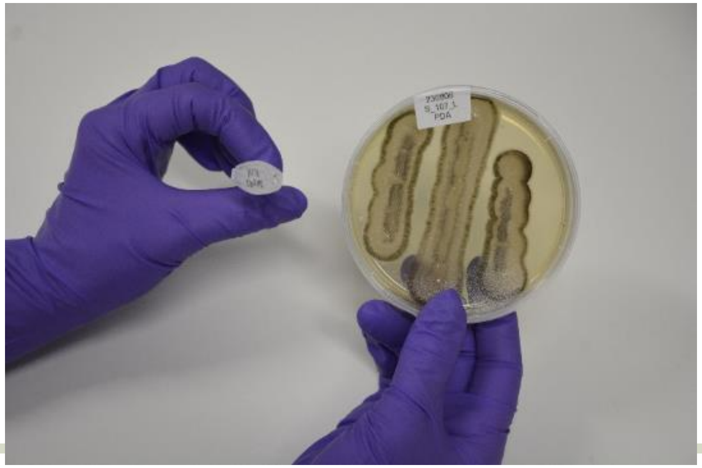


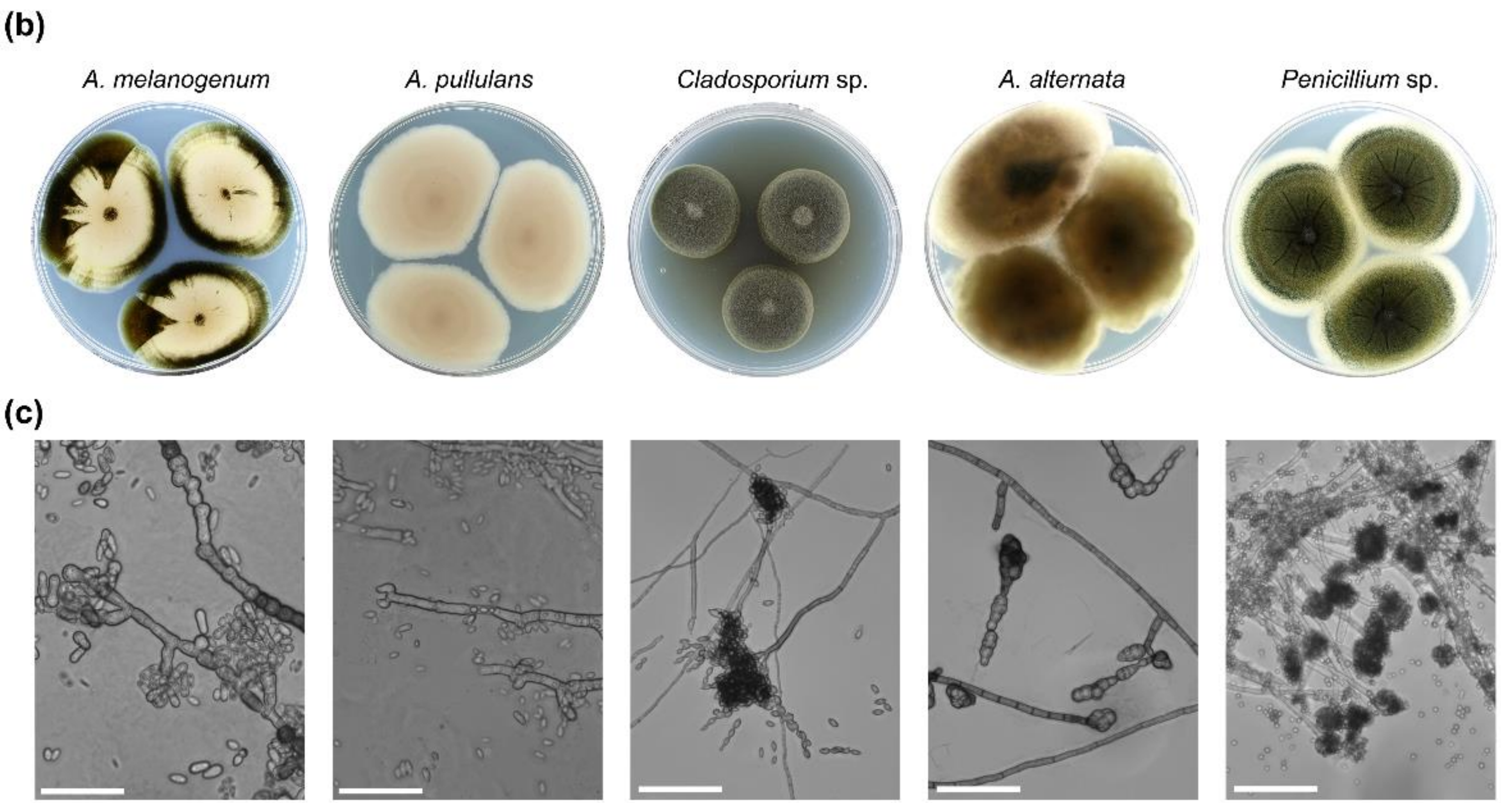


Molecular identification









coatings
MDPI

Article

Assessing the Bioreceptivity of Biobased Cladding Materials

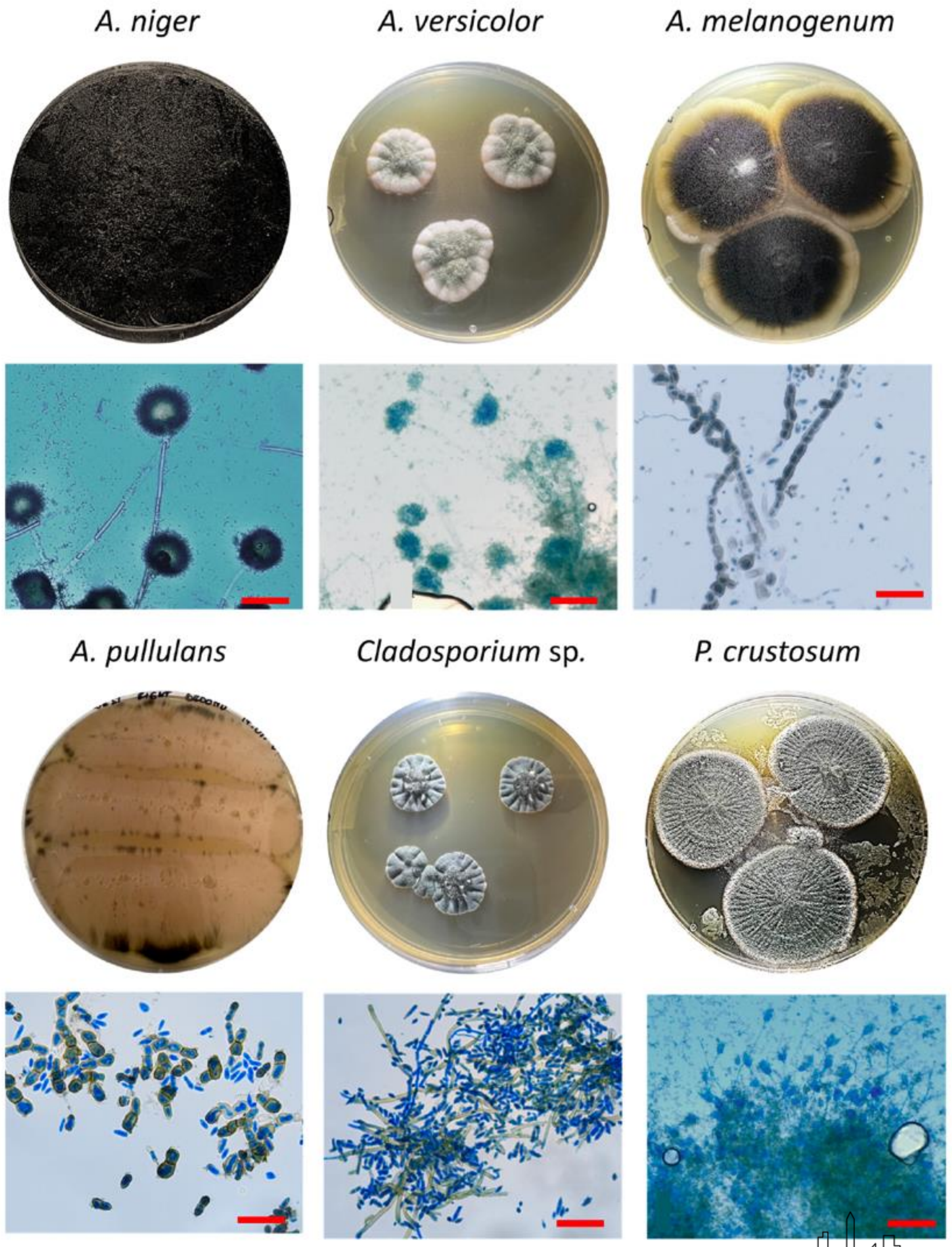
Karen Butina Ogorelec [1,2,*], Ana Gubenšek [1,2], Faksawat Poohphajai [1,2,3] and Anna Sandak [1,2,4,*]

coatings
MDPI

Article

Bioinspired Living Coating System for Wood Protection: Exploring Fungal Species on Wood Surfaces Coated with Biofinish during Its Service Life

Faksawat Poohphajai [1,2,3,*], Ana Gubenšek [1,3], Anja Černoša [1], Karen Butina Ogorelec [1,3], Lauri Rautkari [2], Jakub Sandak [1,3] and Anna Sandak [1,3,4]



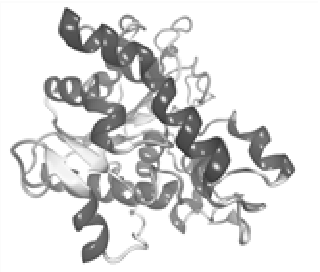
ARCHI-SKIN

Aureobasidium pullulans

ubiquitous

polyextremotolerant

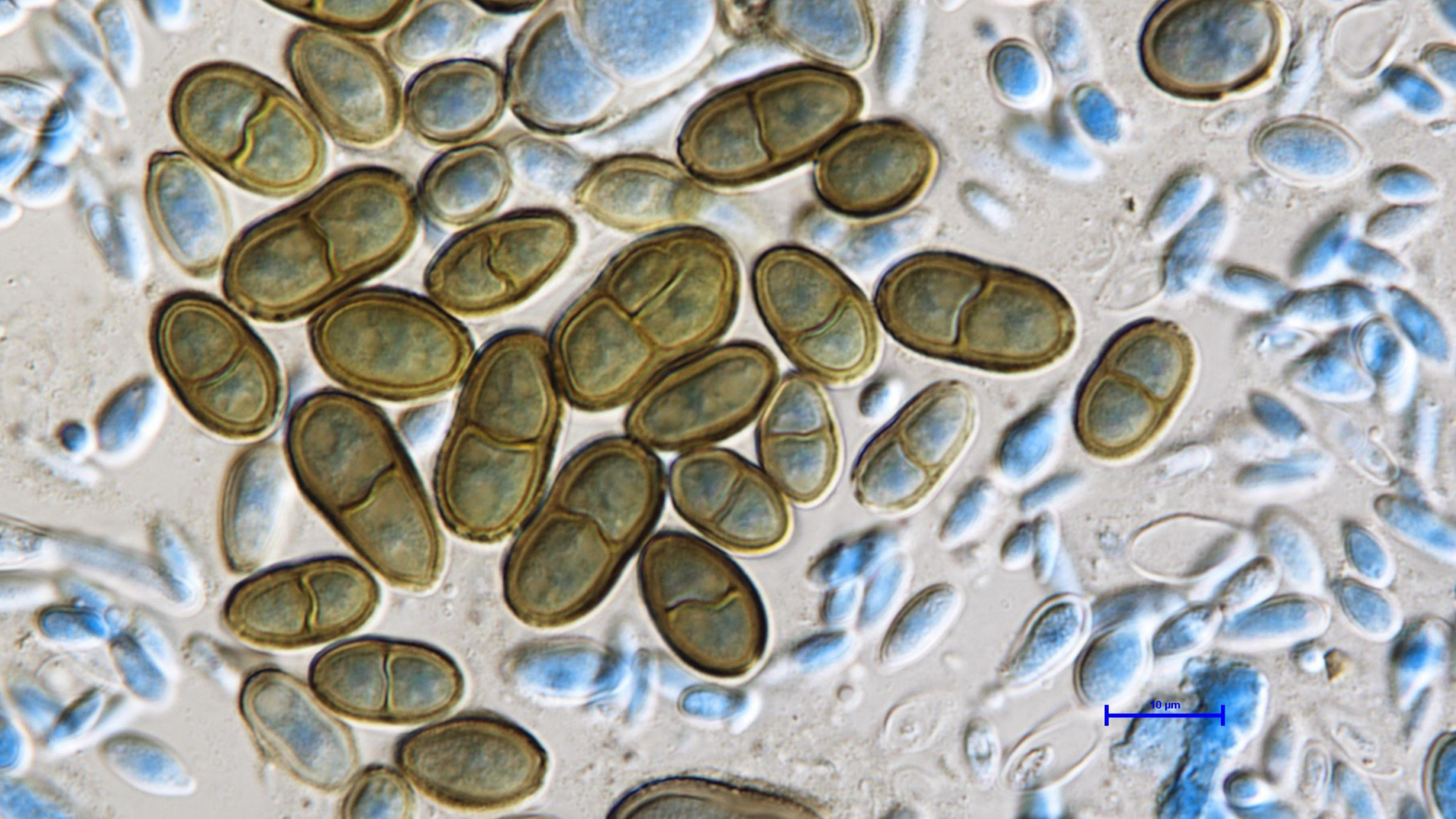
phenotypic plasticity



enzymatic profile

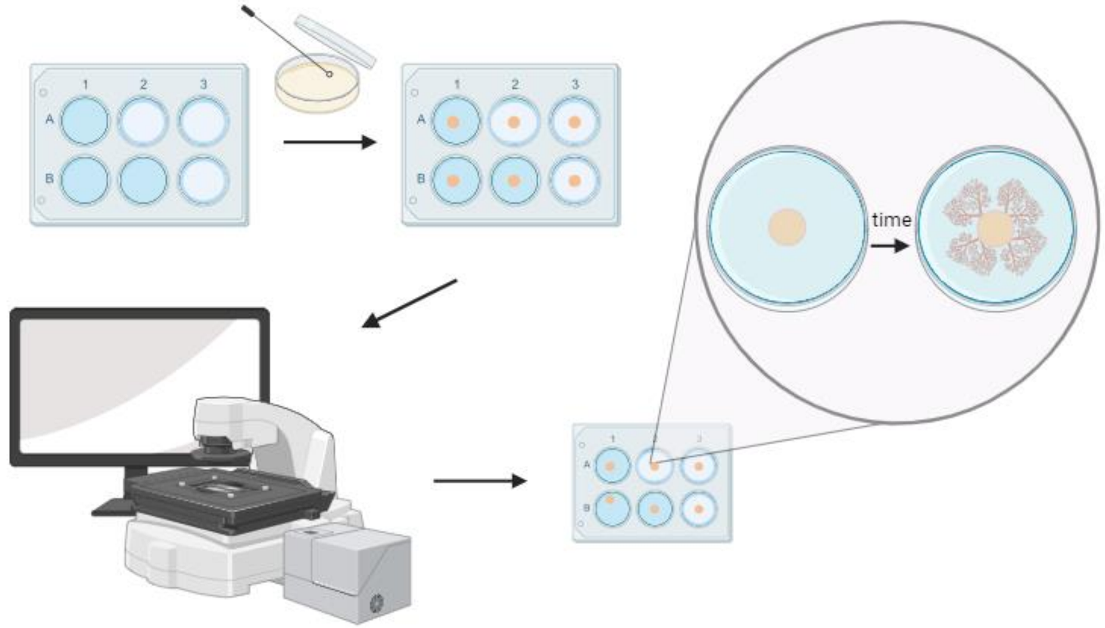
pigmentations

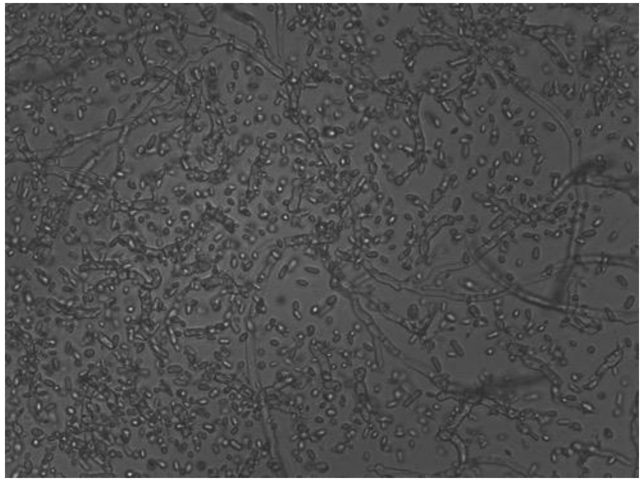
not toxic (BSL1)


10 µm

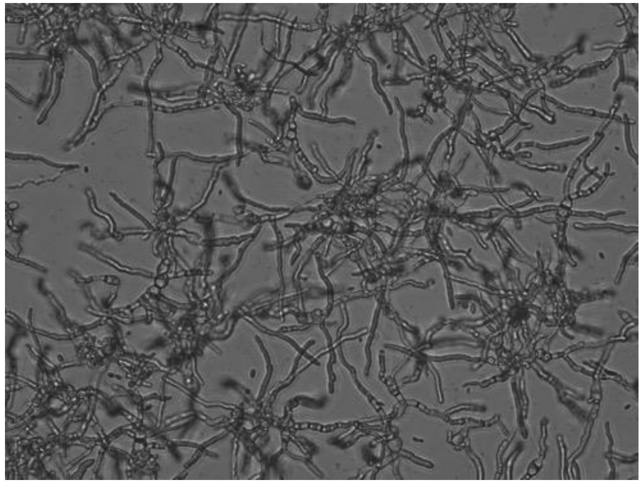
InnoRenew CoE

Live cell imaging

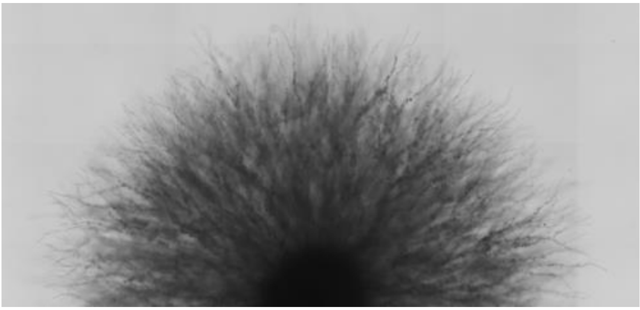




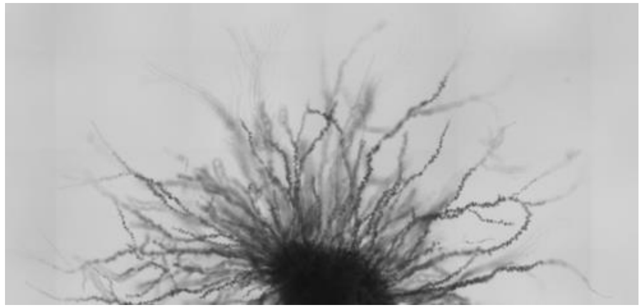
Potato Dextrose Broth (PDB) liquid medium



Yeast nitrogen base (YNB) liquid medium

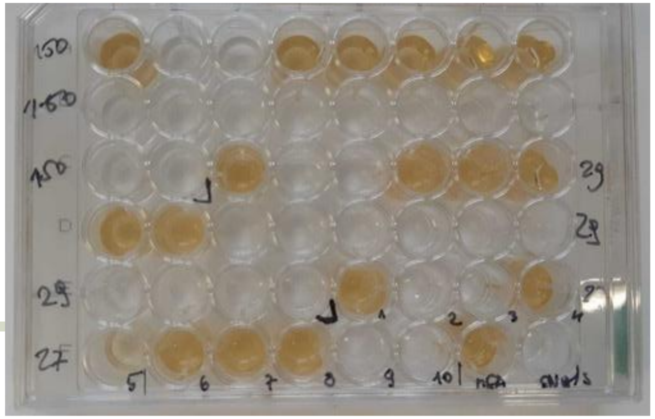


A. pullulans on SNA at 25°C, timepoint 66h

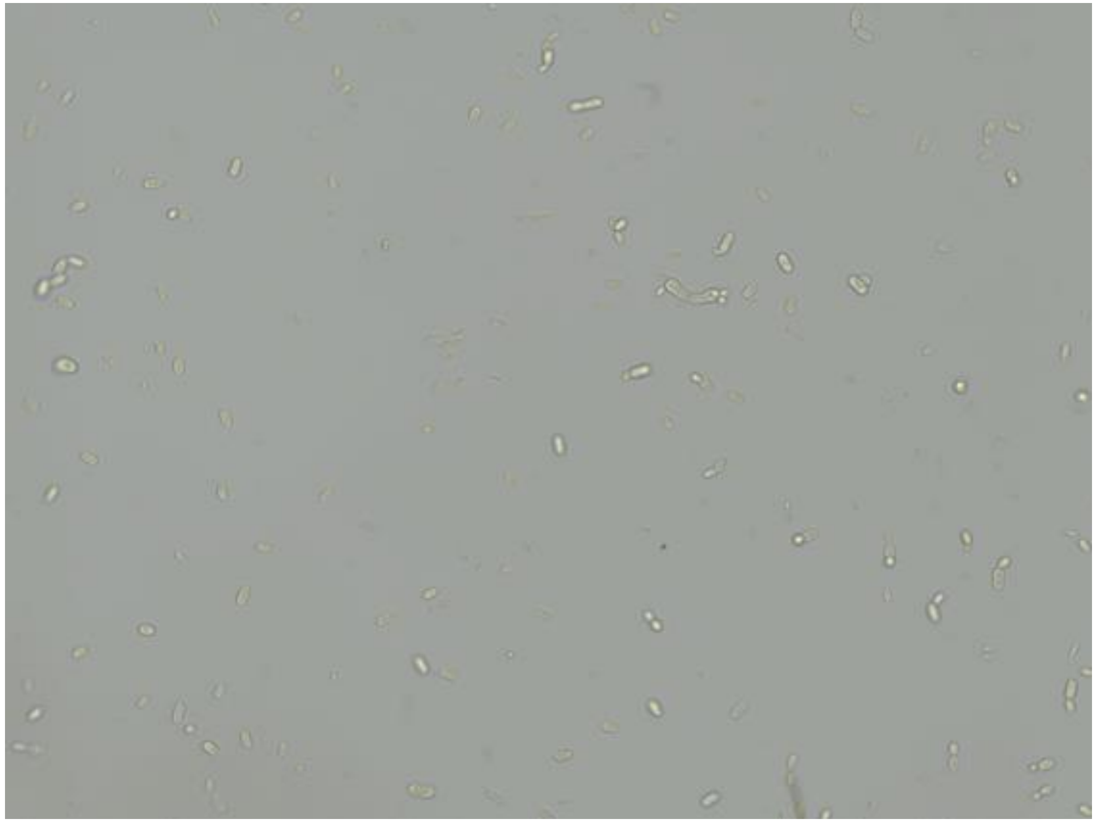


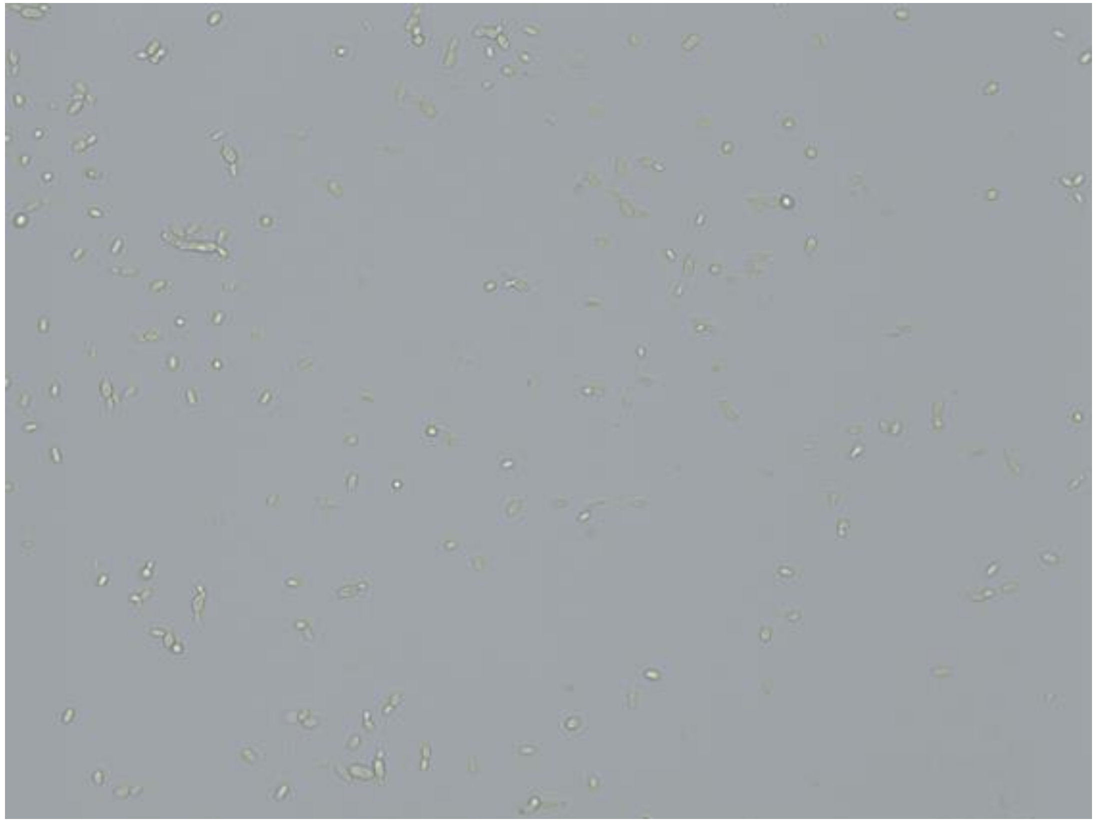
A. pullulans on SNA+0,01% chitosan in 1M glycolic acid 25°C, timepoint 66h

Screening of various strains on various media



Time-lapse microscopy

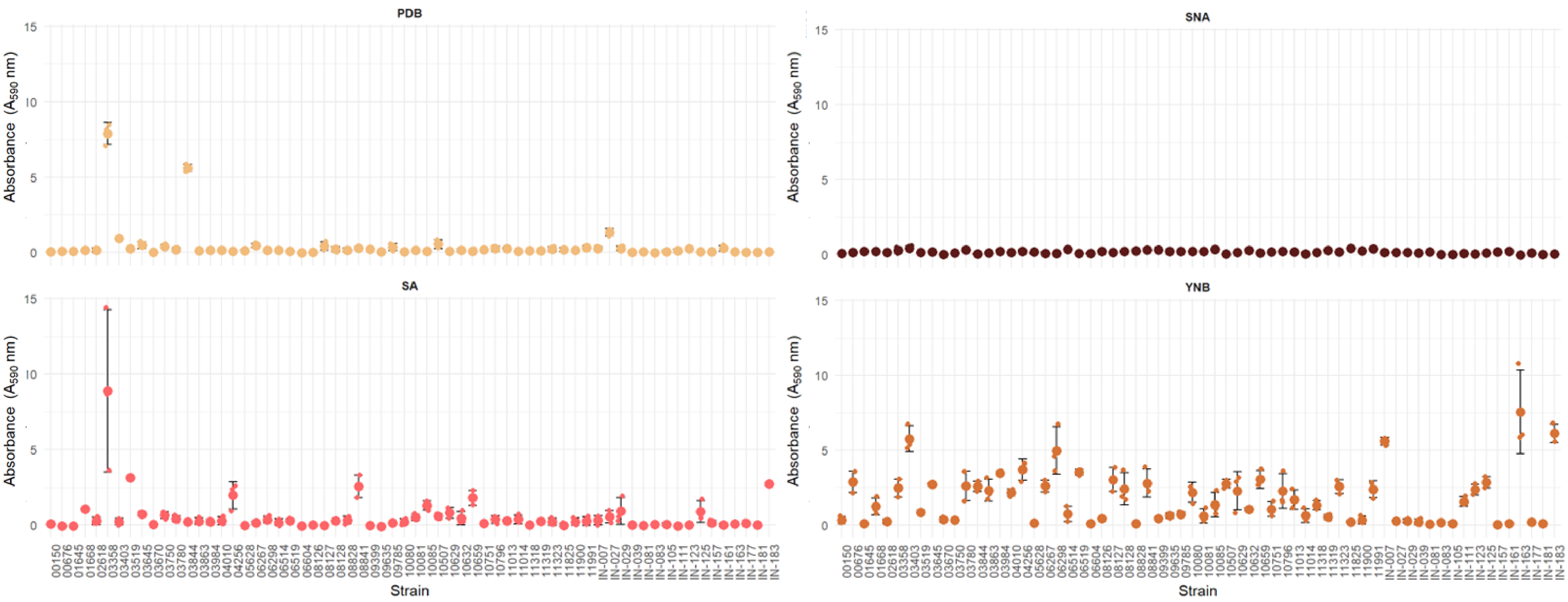




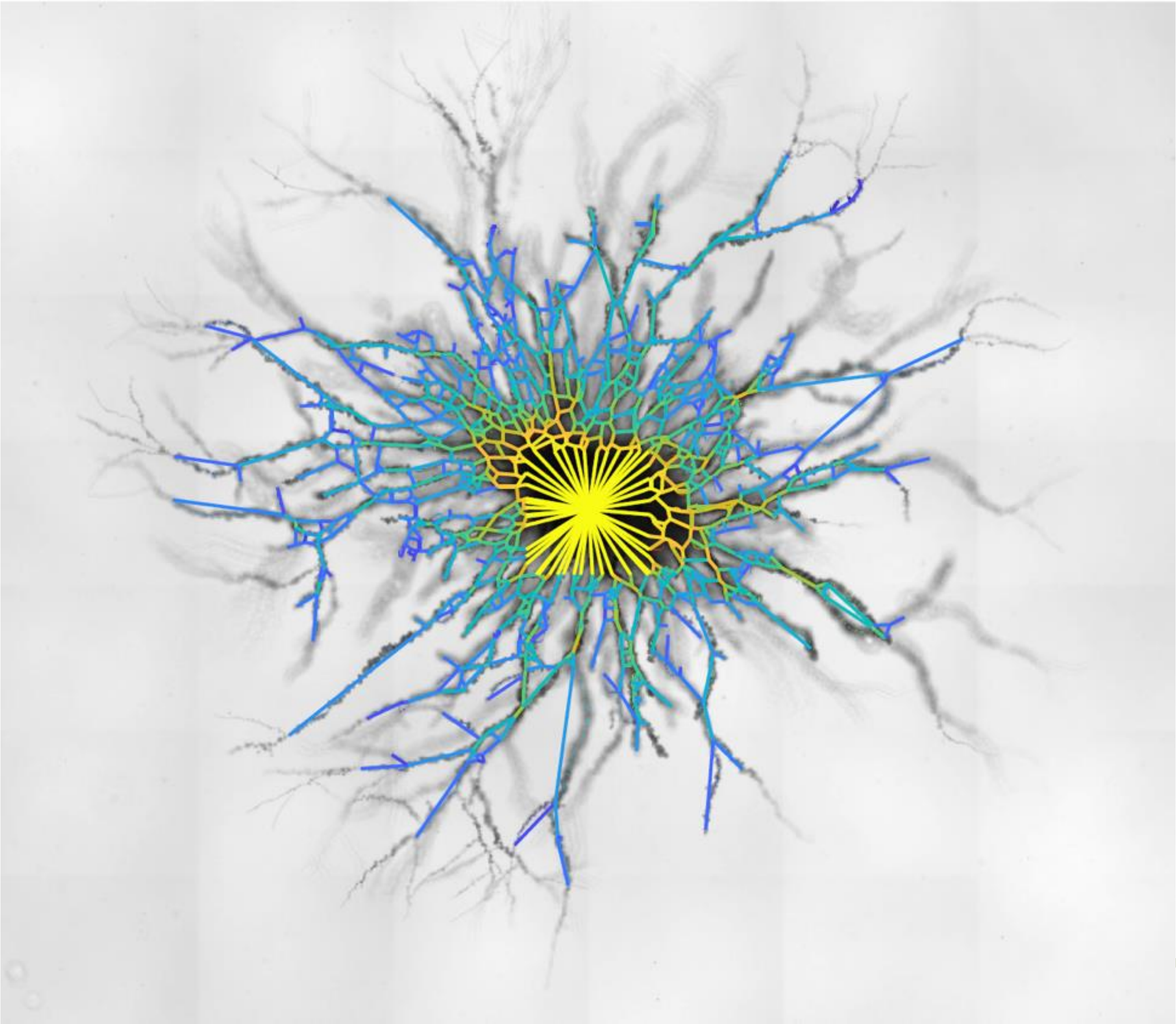
PDB

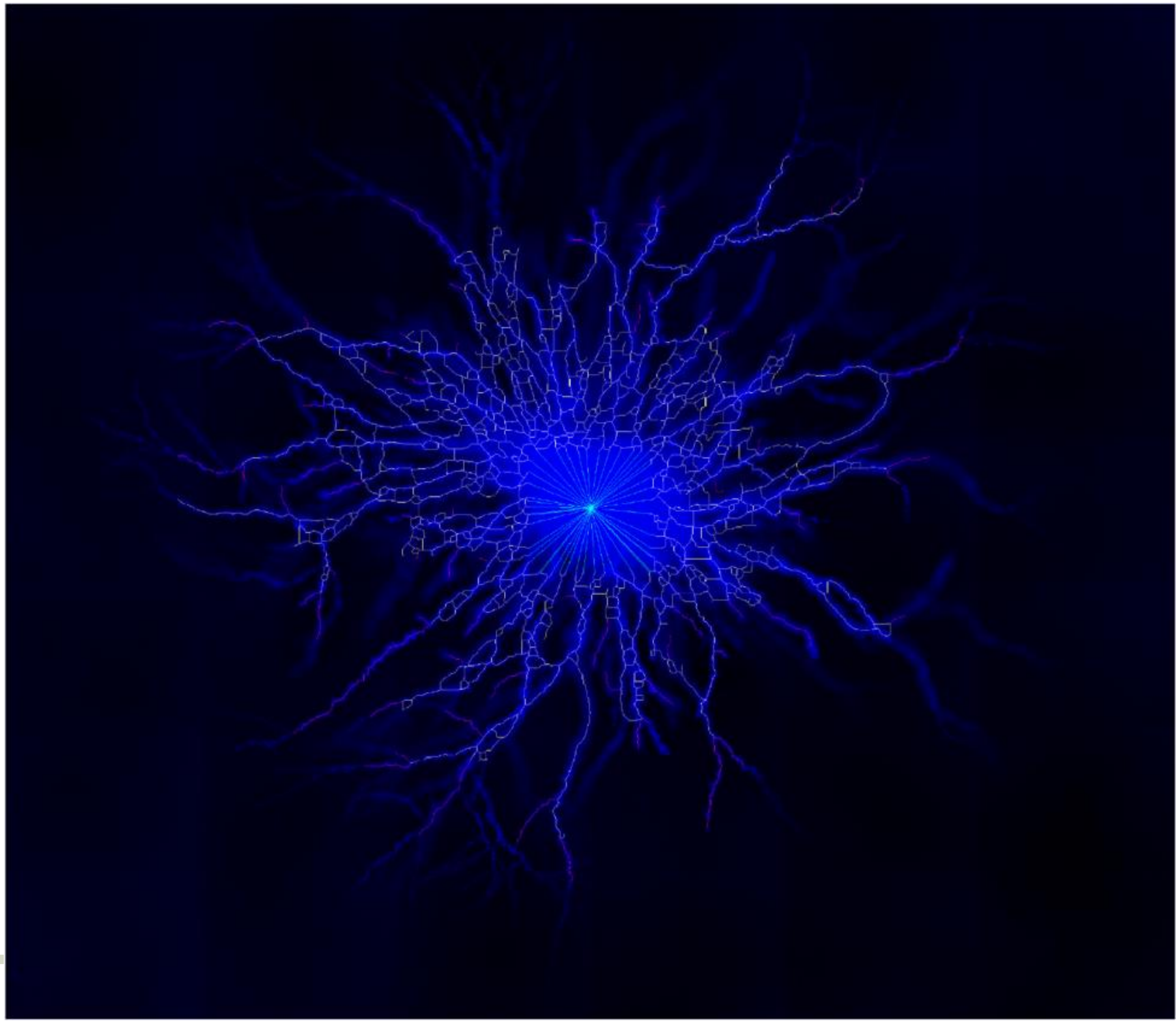
SNB

Screening of biofilm production



Mathematical modelling

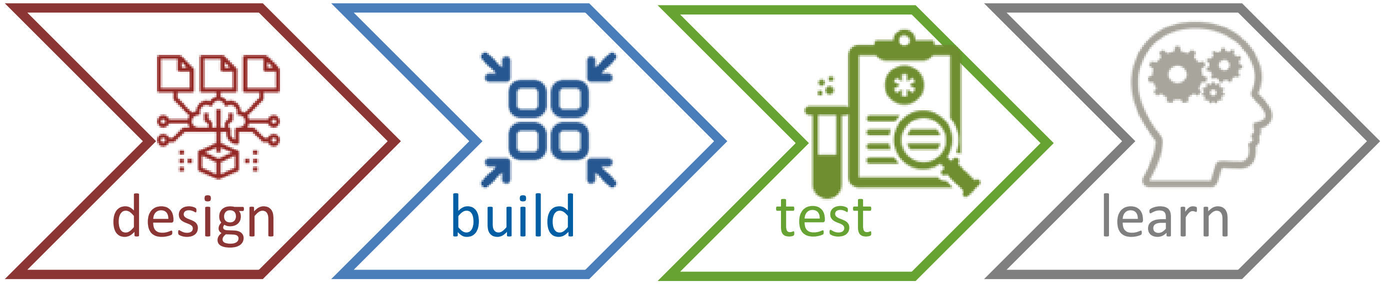


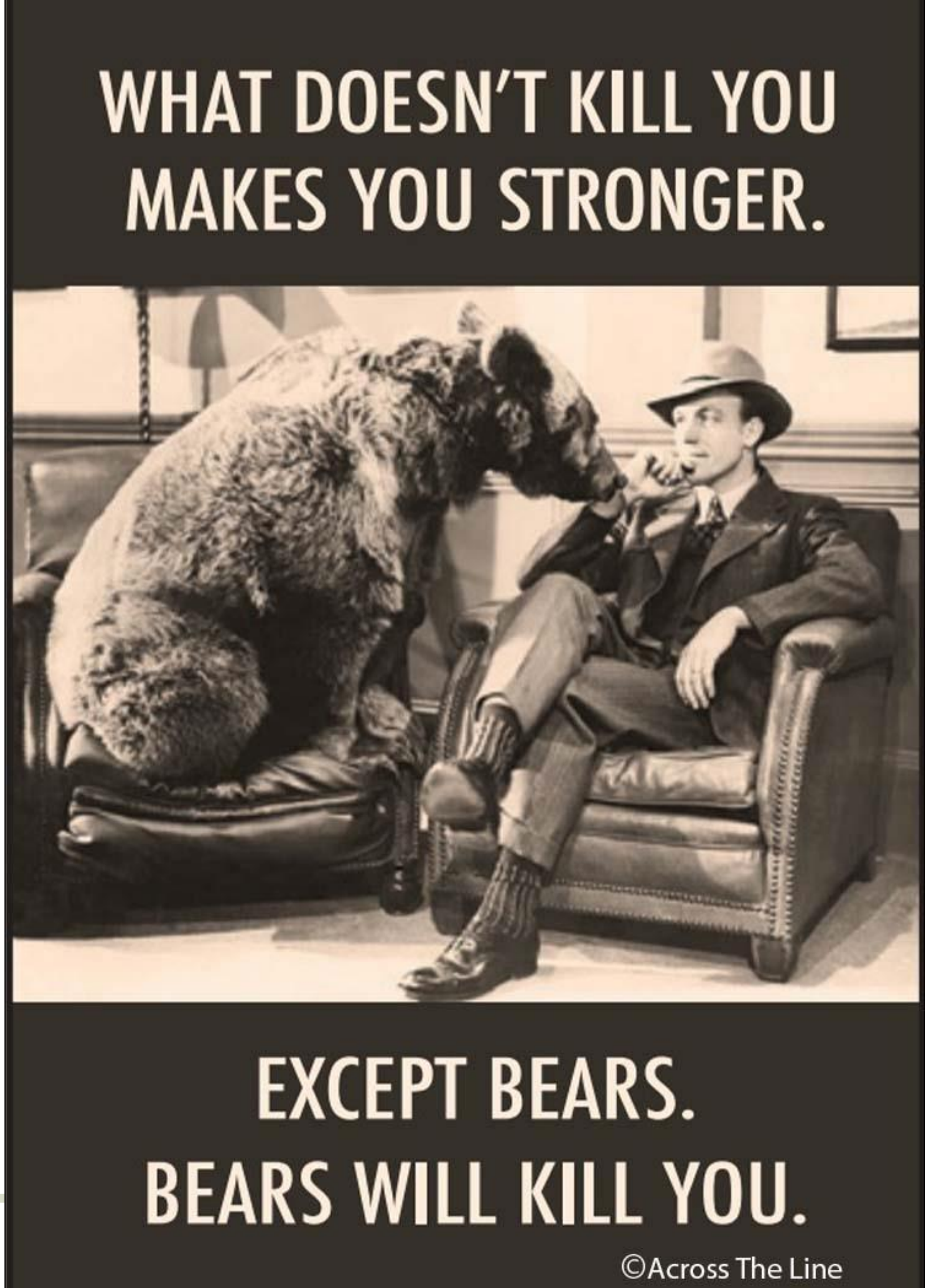


Challenges of ELMs development

- investigation of physical and biological constraints
- viability of living cells
- new fabrication technologies
- process upscaling
- interdisciplinary approach
- safety
- lack of standardization
- public acceptance

How can we boost ELMs development?





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https://www.popularmechanics.com/space/a24639/space-drill-used-by-nasa-astronauts/

Mission Possible

MayaSat-1 will carry 980 biological samples, launching from Vandenberg Space Force Base aboard a SpaceX Falcon 9 rocket. It will deploy the capsule into low Earth orbit at an altitude above 500 km, where it will complete three orbits, passing through the charged polar zones.

Microgravity

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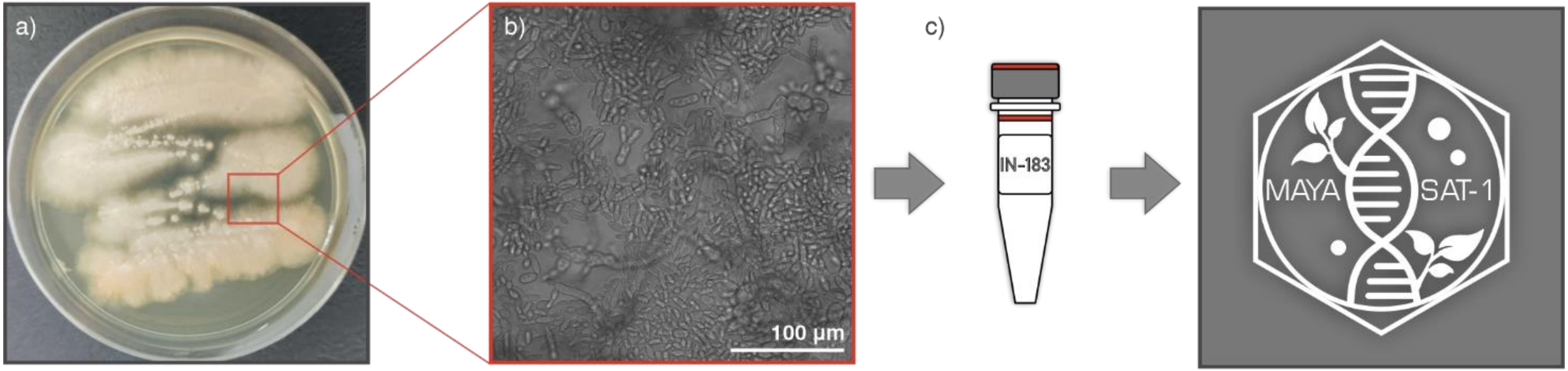
“The design of an experiment can make the difference between success and failure”

MICROBES IN SPACE

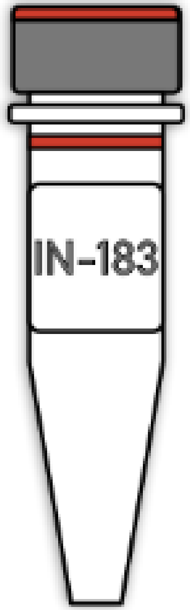
So far, microorganisms have been research subjects or nuisances on space stations, but could they enable longer-distance missions? **By Amber Dance**

ARCHI-SKIN experiment



(a) Fungus *Aureobasidium pullulans* (strain IN-183) cultivated on PDA solid agar medium. (b) Microscopic detail of biofilm structure. (c) Schematic representation of the MayaSat-1 biological payload integration.

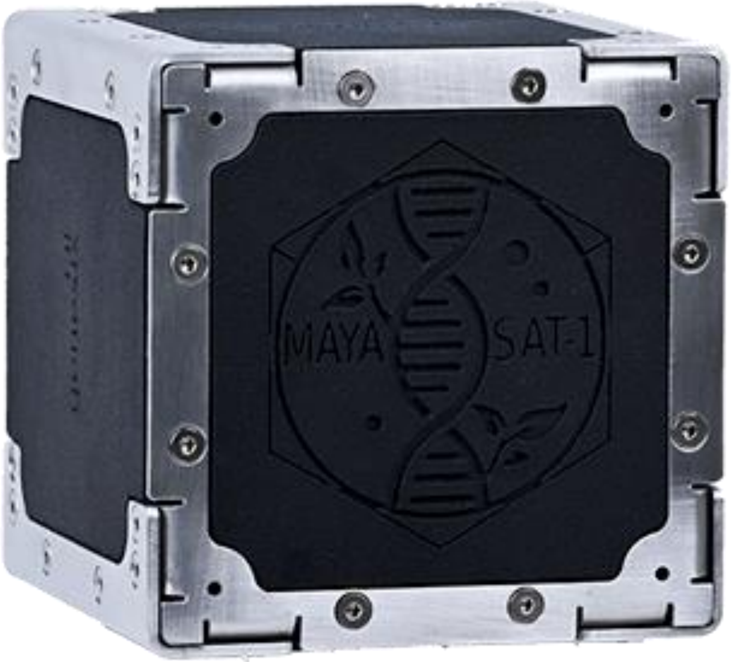
ARCHI-SKIN approach



1 stored at 4°C

1 original strain stored at -80°C

5 payloads integrated within the Mission Possible space capsule



Biofilm analysis

- Microscopy (ESEM and Fluorescent with MitoTracker and Calcofluor White staining)
- Whole-genome sequencing to detect mutations and genetic differences
- RNA sequencing to analyze gene expression and compare protein expression
- Fungal growth and survival (under various UV and oxygen doses, and temperatures)
- Co-culturing with pathogenic fungi on agar plates to observe potential inhibition of the pathogenic growth.
- GC-M and LC-MS to analyze metabolic changes

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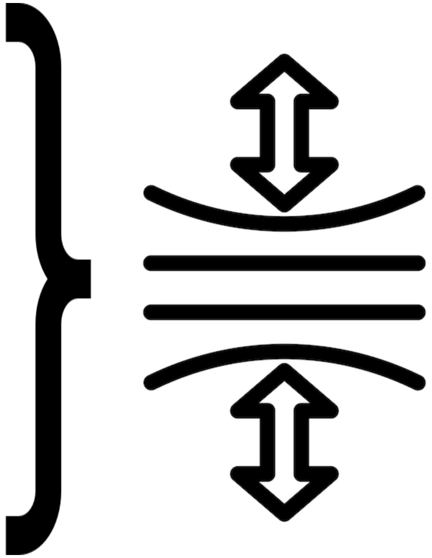
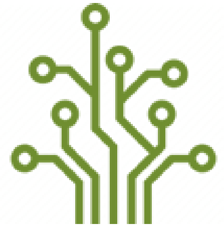
Expected outcome

- Differences in biofilm formation and morphology
- Phenotypic plasticity
- Mutation linked with survival
- Extremotolerance and metabolic shifts
- Epigenetic regulation of adaptation





engineered living materials

interacting, adapting, and responding to environmental changes

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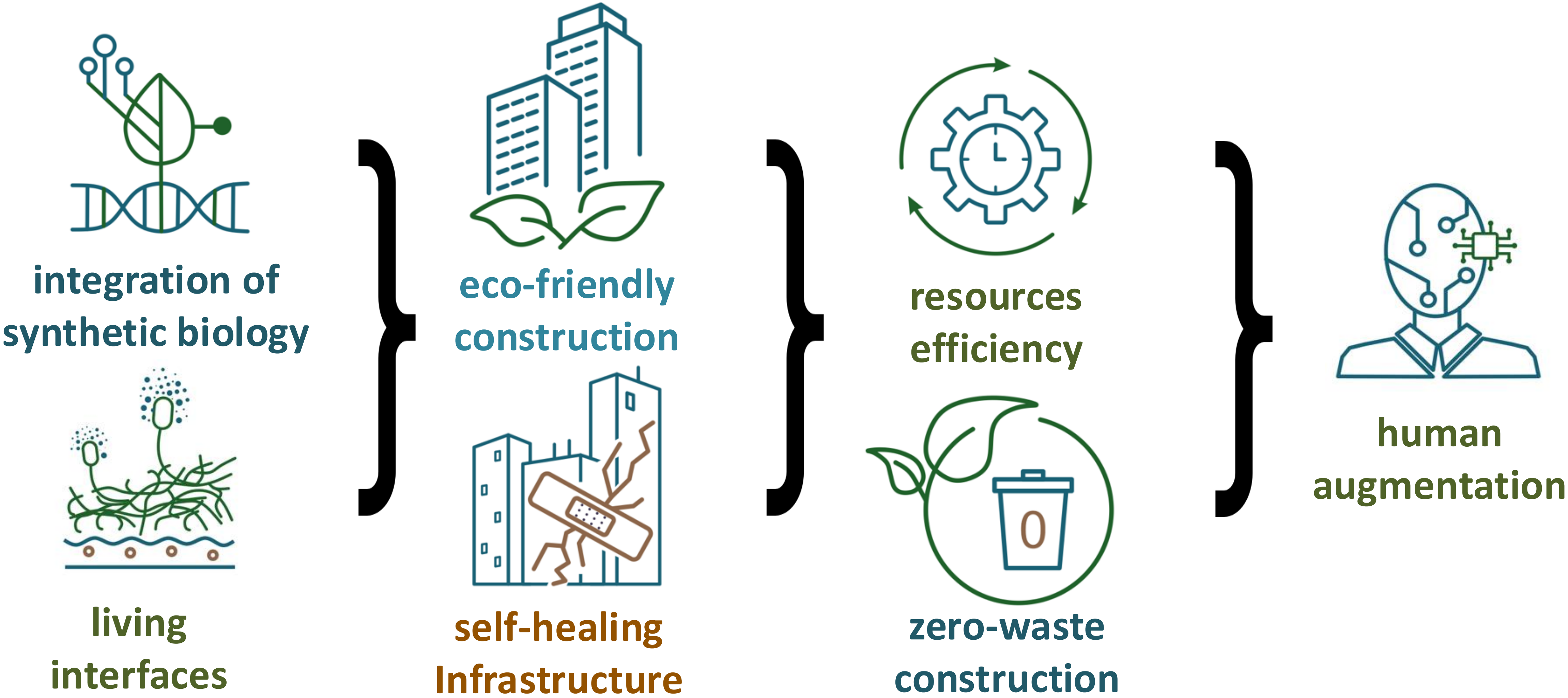
Role of ELMs in resilient architecture



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Space-Driven Innovations in ELMs





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Key benefits for Earth applications

- **Improved Durability**: materials tested for extreme conditions last longer on Earth
- **Lighter Materials**: advances in lightweight, strong composites benefit transportation and sports
- **Innovative Manufacturing**: space-inspired techniques improve Earth industries
- **Sustainability**: self-repairing and recyclable materials reduce waste

Take home messages

Women have always been innovators in science and engineering.
From Marie Curie to Mae Jemison, we've pushed boundaries.

The future of space is not just about rockets and astronauts - it's about bioengineers, material scientists, and innovators like us.

What role will you play in shaping the future of space exploration?

Observe, learn, dream, be brave and curious!

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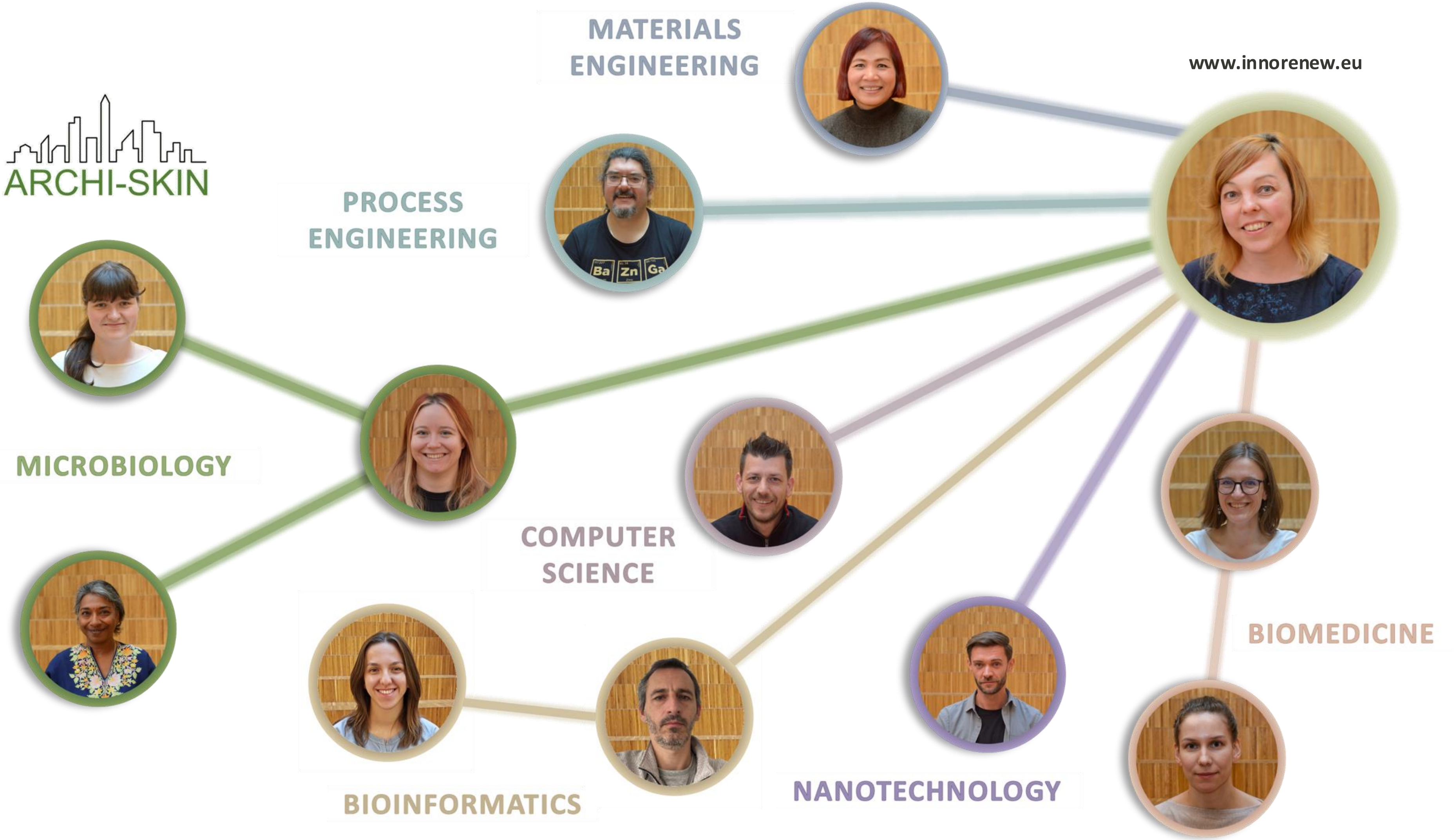
ARCHI-SKIN



European Research Council

Established by the European Commission

This research was funded by the European Union (ERC, ARCHI-SKIN, #101044468). Views and opinions expressed are, however, those of the authors only and do not necessarily reflect those of the European Union or the European Research Council. Neither the European Union nor the granting authority can be held responsible for them.