CO-CREATING GREENER FUTURES:
DEVELOPING AND TRANSFERRING INNOVATIVE BIO-DESIGN MODULES FOR EDUCATION TO ACCELERATE THE GREEN TRANSITION.

Deliverable | D 2.3

OPEN ACCESS BIOFABLAB CONCEPT

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Short Summary

This deliverable (D2.3) provides a detailed exploration of the concept, implementation, and significance of Open Access bioFABLABs, as pioneered by the CoCoon project. Building on the foundation laid in D2.1 and in D2.2, which mapped optimal methods for mainstreaming biodesign, and preparing the stage for the forthcoming deliverable 3.1 'Seeds of Change', this deliverable aims to equip designers and organisations with the necessary tools, infrastructures, and policies to establish bioFABLABs.

CoCoon's Conceptual Framework for bioFABLABs:

• The DIY Bio Kitchen: The essence of DIY bio movement lays at the heart of bio design explorations and must be nurtured in the BioFabLabs. The movement has pioneered methods of designing with nature with only basic household tools and therefore the DIY Bio Kitchen is proposed as a fundamental component of bioFABLABs. This space is designed to merge everyday cooking methods with scientific discovery, utilising waste products and common ingredients in innovative ways to foster sustainable development.
• Essential Equipment and Spaces of BioFabLabs: This document details the essential equipment and spaces required for institutions to set up a bioFABLAB. The framework enhances the DIY Bio Kitchen with research equipment and digital fabrication tools. The bioFABLAB has four interconnected zones defined as the SAFE, PREP, WORK, and GROW zones, each serving a unique purpose in the biodesign process. The framework aims to fulfil Biosafety Level (BSL) 1, which means we are working with living organisms that are not harmful to humans. This setup facilitates a gradual transition from basic biodesign exploration to more complex projects, accommodating a variety of biodesign activities.
• Framework for Innovation: The bioFABLAB is envisioned as a platform for innovation, allowing for the exploration of sustainable practices and amplifying innovation capabilities within organisations. The bioFABLAB space is designed to cultivate innovation through application of biodesign methods. By balancing open access with safety the space can incubate living designs, foster the discovery of new biodesign methods and spark new innovations.

Open Access and Safety Policies:

- Balancing Open Access with Safety: A critical aspect of establishing bioFABLABs is the balance between providing open access to foster innovation and ensuring safety. The document outlines research lab safety protocols and procedures in regards to BSL 1., emphasising the importance of proper training, protective equipment, and risk management.
- Towards a bioFABLAB Charter: Inspired by the principles of the Fab Charter, the bioFABLAB Charter advocates for transparency, open access to resources, community engagement, and ethical oversight. This charter aims to foster an environment where creativity, scientific inquiry, and innovation can thrive alongside safety and accessibility.

Nurturing Biodesign with Organisms:

- Working with Selected Organisms: The document provides guidance on working with various organisms, highlighting the importance of understanding specific equipment needs, establishing the right environmental conditions, and ensuring safety.

D2.3 proposes a comprehensive framework for establishing Open Access bioFABLABs, blending the principles of DIY bio, advanced fab lab technology, and precision bio lab equipment. It emphasises the importance of open access, safety protocols, and the nurturing of biodesign innovation. This deliverable not only serves as a blueprint for the creation of bioFABLABs but also as a catalyst for sustainable innovation and the democratisation of biodesign.

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Introduction
Why is it important to have bioFABLAB facilities?

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In an era where technological advancements are making previously intricate scientific processes accessible to a broader audience, the importance of **bioFABLAB** facilities cannot be overstated.
Open-access laboratories, commonly known as Fab Labs, offer advanced tools for digital fabrication, enabling a wide range of users, including inventors, designers, and scientists, to bring their ideas to life. While these labs have traditionally focused on digital processes, the field of biofabrication is now emerging alongside them. This evolution parallels the growth of digital fabrication, where the maker movement facilitated fabrication in unconventional settings, like garages (Garnier & Capdevila, 2023). Similarly, the DIY bio movement is revolutionising biological processes, turning common spaces such as home kitchens, into hubs for biodesign,thanks to the rise of DIY biofabrication and online platforms that offer open-source projects, tutorials, kits, and community forums that foster knowledge sharing amongst enthusiasts.

DIY setups have significantly contributed to democratising biodesign and digital fabrication, but face limitations, primarily related to the range of materials used and the scale at which creations can be produced. Open workshops like Fab Labs and maker spaces provide unique opportunities for nurturing and accelerate bio-based innovation. These spaces attract a vast community of innovators, learners, motivated makers, solution seekers from various industries, and entrepreneurs.

Fab Labs aim to foster invention by providing access to tools for digital fabrication. They boast an evolving inventory of core capabilities to create almost anything. The construction of the standardised fab lab helped formalise the Maker movement, transforming it from a collection of individual tinkerers to an inclusive maker community. Importantly this standardisation and formalisation of the fab labs and maker movement has enhanced the influence these maker communities *have on education systems (Blikstein & Krannich, 2013, Blikstein 2018).*

Integrating biofabrication into the Fab Lab toolkit will bring biodesign closer to a wider audience, and propel DIY solutions further. The standardisation of tools and practices in biofabrication is crucial for several reasons. First, it ensures that all users adhere to the same safety and quality standards, reducing the risk of accidents or misuse. Second, it simplifies the process for new users, who can follow standardised instructions and guidelines. Third, it can propel the DIY bio movement even further in their explorations. Crucially standardisation with shared methods and tools allows users creators across the globe to collaborate in developing solutions.

This document aims to bridge the gap between DIY bio-kitchens and bio-research labs using Fab Labs as a platform for setting such standards. It outlines what is required to set up an **Open Access bioFABLAB**. This integration is crucial to providing organisations the capabilities to set up such spaces allowing enthusiasts and practitioners with more opportunities to experiment and innovate with bio-based/ living materials, thus pushing the boundaries of what is achievable beyond traditional research institutions.

The CoCoon framework for biofablab

While not a governing body, the CoCoon consortium aims to play a role in shaping the future of bio fabrication. Research shows that shared methods, tools, and knowledge can boost the involvement of new institutions and individual makers (Rayna & Striukova, 2019). As such, we've developed a framework as a foundational step towards standardisation bioFABLABS. This framework is adaptable for both new and existing labs, as well as educational settings like vocational schools and universities.

Recognizing the dynamic nature of bio-design, we intend for this framework to be a living document, evolving through ongoing collaboration with the bio-design community. We openly invite critique and feedback, fostering lively discussions. Our goal is to craft a bioFABLAB module that can be easily replicated globally, with shared methods to enhance collaboration and speed up its integration into mainstream use.

We acknowledge that, despite extensive literature reviews and expert inputs, some methods might have been missed or deliberately postponed for simplicity. This is a common challenge in standardisation efforts (Norman, 2013) , but it underscores the value of creating a shared reference framework, it gives us - the bio design community - something to work with together.

At its core, the framework aims to structurally define the essential methods and tools for biodesign, creating a standard bioFABLAB inventory that complements the previously established Fab Lab inventory. This inventory will be particularly beneficial for schools and fab labs looking to expand their capabilities into biodesign, allowing them to integrate Bio-Fab inventory into their existing facilities. By offering global access to learning pathways focused on bio-based fabrication, we anticipate a transitional shift in the Fab Lab network towards sustainable fabrication practices.

The standardised fab lab kit is designed to enable and encourage users to design and create items that can be shared globally. This not only includes sharing designs and machine settings but also practical tips to ensure digital replicability. The framework also maintains a degree of flexibility, allowing labs to supplement with additional tools as needed. Ultimately, increasing access to robust infrastructure for grassroots design communities lays the groundwork for further growth and innovation in the biodesign field.

Bridging Home DIY and Research Labs: A Path to Innovation

The fusion of DIY culture and research lab methodologies in a structured Fab Lab setting, presents an opportunity for innovation. DIY culture thrives on individual creativity, empowering people to independently create, modify, and repair items sometimes with professional guidance. In contrast, research labs represent the pinnacle of professional scientific inquiry, with controlled environments and advanced equipment leading to groundbreaking discoveries. Fab Labs have successfully bridged these two domains in the field of digital fabrication, and applying this structure to mainstream bio design holds great promise for further innovation.

The Importance of Bridging the Gap

Mutual Benefits: DIY enthusiasts inject a distinct brand of creativity and resourcefulness into the research sphere, potentially sparking new innovations. Research labs, on the other hand, provide structured environments, resources, and knowledge that can significantly enhance the efficiency and quality of DIY projects.

Biofabrication and Biodesign: These emerging fields illustrate the necessity of blending DIY enthusiasm with lab precision. Biofabrication involves producing complex biological products, requiring clean, segregated spaces to avoid contamination and standardised methods for replicability and reliability. Biodesign, which combines biological science with design principles, demands a deep understanding of both fields to ensure ethical, sustainable, and innovative outcomes.

Digital Technologies: While many digital technologies are clean and can be situated outside traditional workshops, others, like milling, moulding, casting, and some electronics, require specific settings.

Space Utilisation: Understanding how users will engage with the space is crucial. This involves strategic placement of tools determining which tools should be grouped together for efficiency and which need isolation, especially to prevent contamination from dust, fumes, or particles.

Community and Collaboration Spaces: Spaces for informal discussions and social interactions are vital for fostering a culture of sharing and innovation but must be thoughtfully positioned away from sensitive machinery and biological work areas.

Guidance in Biodesign: Having a qualified individual in biodesign is essential, especially as it's a nascent field. This person could have a diverse background—be it a biologist, a designer experienced in biological processes, or a biology teacher—but must possess a strong foundation in biological sciences and a passion for biodesign.

Facilitating Exchange: Such professionals not only guide safe and effective project execution but also act as conduits between DIY enthusiasts and research labs, enhancing the exchange of ideas and practices.
Community Interaction: The heart of Fab Labs lies in the meeting of like-minded individuals, exchanging ideas, and fostering a vibrant community.

Resources and Shift in Production: Access to online resources and a shift in how we produce and consume items underscore the importance of this integration.

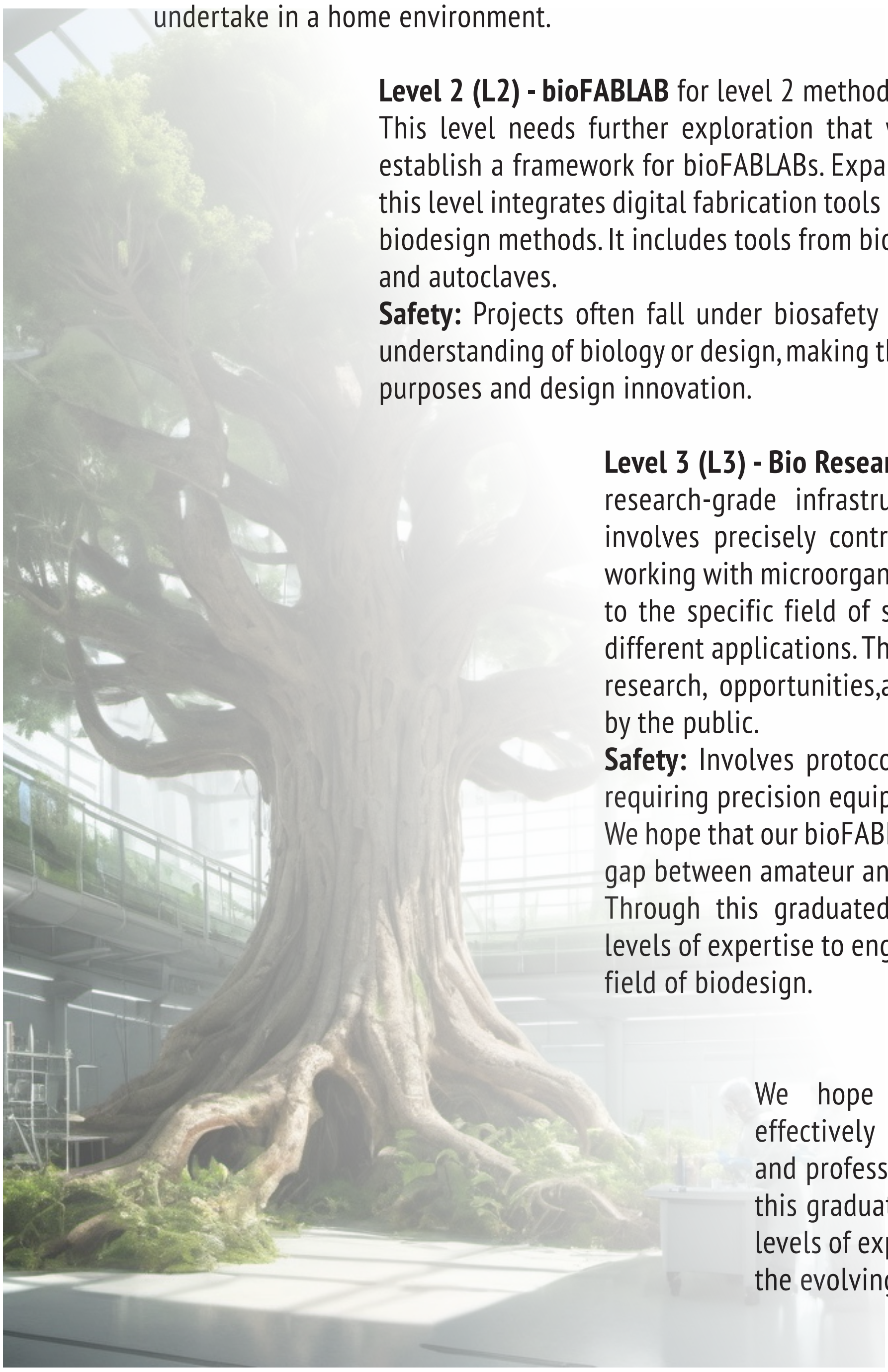
Adopting bio design methods into open access Fab Labs and makerspaces can forge a vital synergy between DIY bio experimentation and research discipline. Such an integration has the potential to revolutionise our approach to scientific exploration and creativity. This synergy could lead to innovative solutions and significant advancements, fundamentally changing how we perceive and interact with the realms of biology and design.

Part I - defining the gap and mapping

Our vision is to bridge the substantial gap between amateur DIY bio enthusiasts and professional research laboratories. The concept of a bioFABLAB is a fusion between a fundamental biology classroom and a fabrication lab. This initiative brings the creative capabilities of designers and students closer to the cutting-edge work typically seen in research laboratories. Rooted in the principles of the DIY bio movement, which has revolutionised access to science education and hands-on learning, BioFABLAB serves as a dynamic space where creative experimentation melds with digital fabrication technologies.

We envision closing the gap between DIY bio and professional research labs, our mapping of biodesign methods biodesign methods has allowed us to define three distinct levels:

Level 1 (L1) - DIY Kitchen Lab: Rooted in the established DIY bio movement, this level is accessible and ideal for at-home biodesign projects. It utilises everyday kitchen tools like pots, blenders, and jars. Simple sterilisation is achievable through methods like rubbing alcohol or boiling water. Basic hand tools are used to enhance customization, allowing for greater creativity in biodesign projects.
Safety: Projects at this level do not require a biosafety classification, making them safe and easy to undertake in a home environment.



Level 2 (L2) - bioFABLAB for level 2 methods of bio design:
This level needs further exploration that will be laid out here to define and establish a framework for bioFABLABs. Expanding upon the foundation set by L1, this level integrates digital fabrication tools like 3D printers and laser cutters with biodesign methods. It includes tools from biology classrooms such as microscopes and autoclaves.
Safety: Projects often fall under biosafety level 1 (BSL-1)[1] and require a basic understanding of biology or design, making them highly applicable for educational purposes and design innovation.

Level 3 (L3) - Bio Research Lab: This advanced level requires research-grade infrastructure for intricate experiments. It involves precisely controlling environmental conditions for working with microorganisms. The equipment varies according to the specific field of study, ensuring tailored solutions for different applications. This level harbours emerging biodesign research, opportunities,and development often unreachable by the public.
Safety: Involves protocols that fall under BSL-1 and higher, requiring precision equipment and high-level expertise.
We hope that our bioFABLAB framework effectively bridges the gap between amateur and professional biodesign exploration. Through this graduated approach, allow individuals at all levels of expertise to engage in and contribute to the evolving field of biodesign.

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[1] https://en.wikipedia.org/wiki/Biosafety_level

MOBILISING BIODESIGN IN FAB LABS?

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In the recent years, there has been a rise of initiatives that merge biodesign capacities into makerspaces. Notably, the do-it-yourself biology (DIY-bio) movement has democratised the ability to work with biological processes into citizen science. With this movement proliferated DIY-biolabs. Originally, DIY-biolabs have often been referred to as the amateur "garage", "basement", and "kitchen" science (Jen, 2015), yet over the years have expanded into institutionalised spaces such as academic and organisational spheres (e.g. MIT DIYbio in USA; Biomakerspace in Cambridge, UK) (Erikainen, 2022). The biohacking afforded in these spaces range from kitchen-biology such as fermentation practices, to most predominantly DNA sequencing and genetic modification.

Although still in affinity with the DIY-bio, CoCoon's approach diverges from such popular hacker practices, by shifting our emphasis from synthetic biology towards the creative biofabrication afforded by these biological processes. In other words, rather than focusing on democratising science (i.e. tools and equipment to work with laboratory biological protocols), we are more interested in fostering design (and artistic) approaches to biology through tinkering. In this sense, our framing of bioFabLab is the hybrid between a basic biology classroom and fab lab – spaces which foster creative tinkering and innovation with biological processes, in combination with digital fabrication technologies.

In our framing of the bioFABLAB, the "bio" component comes from biodesign, which encompasses a variety of strategies from using nature as a resource (bio-based design), taking inspiration from nature (bio-informed design), to treating nature as a collaborator (bio-integrated design) and programming nature (bio-engineered design) (see Deliverable 2.1 "Policies Review - Barriers and opportunities for mainstreaming biodesign education and practices"). Examples of these practices are often showcased in the context of the built environment (e.g. Mycoscape by IAAC), in product design (e.g. Mycelium furniture by Caracara Collective; Pulp foam by CHEMARTS) and in the fashion industry (e.g. Grow Your Own Couture by Piero d'Angelo) (see D2.2 for details and more case studies).

In the concept of the bioFABLAB, the"fab lab" component builds upon the physical and social platforms (makerspaces) stemming from the Maker Movement. Fab labs materialise the effort in democratising access to digital fabrication equipment, tools and ideas that are shared and nurtured collectively in networked communities. Fab labs are ideologically more concrete than the more generalised approach to makerspaces. The Fab Charter, for instance, outlines the basic principle of fab labs, and although possessing considerable variation. Similarly, the Fab Foundation (www.fabfoundation.org) has established a guideline on how to set up a fab lab. This guideline includes an inventory of hardware, software and materials, key strategies, proposed layout plans, and tips on how to engage the various users - from the general public, students, entrepreneurs to government stakeholders.

The hybridisation of biodesign and fab lab approaches affords unique perspectives for education. On one hand, fab lab supports the (often messy) work of tinkering, and "failure" is embraced as part of the learning process, whereby rapid prototyping iterations are done to find new and 'better' solutions for the project. In addition, open source sharing principle within the physical lab setting (peer-2-peer sharing), as well as beyond it (global fab lab nodes and networks), enables collaborative learning. Digital sharing platforms such as GitHub and Thingiverse, together with open sharing of blogs by FabAcademy students strengthen the sense of the knowledge commons, in addition to the access to physical tools, equipment, and spaces.

On the other hand, a basic biology classroom enables students to carry out experiments with scientific protocols, and often under controlled environments. Through these educational experiments, students develop theoretical and systemic understandings of biological processes, as well as how to interact with organisms using different tools and methods. It is also a space to develop their skills in asking generative questions, designing investigations, constructing models, developing explanations, and engaging directly with the ethics of working with other forms of life (Czerniak, 2018).

The intersection of these makes it possible for a ***DIY approach to biofabrication, in which learning-by-doing is mobilised for working with biological processes.***

bio(FAB)LABS: the current landscape

The above framing informed our scoping study of the existing initiatives aligning with our endeavour. Unlike fab labs which identify themselves under a single term, these initiatives exist under diverse names - including "atelier", "kitchen", "DIY space", "bio-lab", "grow lab", "green lab", "biodesign centre" – and therefore extensive desktop research was conducted through databases, network websites, and social media with various search terms. In our search, we focused on facilities which offered a creative exploratory approach to entry level biodesign, which does not have biosafety classification or operating at biosafety level 1 (BSL1), and predominantly working with unmodified organisms. From this research, we have identified 53 facilities, from which we extracted openly available information on their spaces, equipment, materials, core approaches, and outreach initiatives. Some of these labs were contacted and interviewed.

The facilities can firstly be classified according to their organisational context. Most bio (fab)labs under our scope exist in academic contexts in forms of educational makerspaces or research facilities. The second most common are makerspaces by independently operated initiatives, usually by non-profit organisations. Few are commercial makerspaces which are privately owned for-profit purposes, or stem from grass-roots community efforts. Various initiatives run across all organisational contexts, from biodesign public workshops, programmes (e.g. Fabricademy's biodesign module), short courses (e.g. Nordic Biomaterials summer course at Aalto University), talks/lectures, and fellowships and residencies (e.g. Future Materials Fellowship at Jan van Eyck Academie).

The integration of biodesign capacities into fab labs or makerspaces is still an emerging endeavour, and encompasses a broad range of approaches. On one end of the spectrum, fab labs can accommodate provisional biodesign workshops by bringing in basic kitchen equipment and setups (e.g. for making starch bioplastics). On the other end, scientific laboratory facilities with specialised and optimised equipment for biodesign research, may also combine (digital) fabrication techniques. In between these two ends of the spectrum are a variety of (fab) lab setups which are equipped with tools and materials useful for fostering biological processes, such as incubators, autoclaves, bio-printers, and temperature-controlled growing spaces.

The DIY culture inherent to fab labs extend beyond the Making of the biomaterials and products, to the Making of necessary equipment. For instance, some labs make their own DIY incubators and microscopes using open-access instructions or online tutorials. Others have hacked their 3D printers, customising them for biomaterial printing. Aligning with the DIY ethos is the idea that instead of purchasing ready-made tools and equipment, one's creativity is exercised in the problem-solving of the alternative ways in which a process can be achieved. Moulds for growing mycelium can be sourced commercially, yet many prefer to design and make their own, or even to find (or scavenge) materials from scrap waste and to assemble a mould (author interview with Caracara Collective, October 2023). Autoclave for sterilisation – which is a costly equipment and not accessible to all - can be replaced by a household pressure cooker, or even boiling water in a pot. These practices, which differ from the tightly controlled experiments in scientific laboratories, not only offer space for creative 'tryouts' but also for accidental discoveries to unfold.

The "bio", combined with the "fab lab" ethos highlights the criticality of both resourcefulness and culture associated with biological knowledge and community making practices. Many labs are encouraging the use of local waste streams as material ingredients, and furthermore, for their practices to stem from local culture and needs. Lifepatch in Yogyakarta, Indonesia, is an excellent example of a community initiative which works with local culture and needs. Farmers participate in the lab to make organic fertilisers, local citizens are invited to create devices to measure E. coli bacteria content in river water, and workshops are held on cultural fermentation technology (e.g. tempeh, alcohol, etc.) (Fong, 2017; Siagian et al., 2016). In the West, local and cultural embeddedness still seems to be weak and requires further emphasis. We believe that highlighting the "messy" practice of growing and experimenting with biomaterials, as well as the involvement of local stakeholders and cultures, would afford greater dialogue within the local ecosystems – as a generative, respectful, and mutual collaboration between both human and more-than human realms.

CASE STUDY BIOLAB LISBOA - INSPIRING THE FUTURE

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BioLab Lisbon, under the guidance of Rafael Calado, the space/project coordinator, exemplifies a successful bio fab lab model. It commenced its initial steps towards implementation in 2017 and officially opened on January 13, 2022.

The lab is a collaborative effort involving the Lisbon City Council (Economy and Innovation/Innovation and Strategic Sectors), the University of Lisbon - Faculty of Sciences (FCUL), and FCiências ID, an association dedicated to science research and development.

BioLab Lisboa facilities. Image retrieved from: https://amensagem.pt/2022/08/10/bio-lab-arroios-lisboa-jovens-aprendem-potencial-biotecnologico-cidades/

Policies and strategies

BioLab Lisbon operates with a strategic approach covering implementation, maintenance, staffing, equipment, space, and security. A three-year strategy is in place, with the lab currently in its second year.

Maintenance: Regular schedules for equipment and activities are followed, aligning with the ongoing implementation strategy.

Staffing: The team includes a coordinator, a biologist/microbiologist, a project manager, and part-time back-office support.

Equipment: The lab boasts a range of equipment including incubators, centrifuges, electrophoresis and transilluminators, thermocyclers, and more specialised tools like a photo-bioreactor and DNA/RNA sequencing equipment.

BioLab Lisboa - Young Creators Programme. Image retrieved from: https://amensagem.pt/2022/08/10/bio-lab-arroios-lisboa-jovens-aprendem-potencial-biotecnologico-cidades/

Balancing safety and open access

BioLab Lisbon is open to the entire city community and visitors, with one open day per week for project proposals and scientific skill assessments. Experienced users can work more independently. The biolab space is designed to direct users to the appropriate areas and create barriers between novices and potential biohazards.

Open Access Days: Once a week, the lab opens its doors to the city community and visitors. Prospective users submit project descriptions and their scientific competencies. Those with demonstrated ability can work independently, while newcomers receive staff assistance.

Project Development: The lab welcomes proposals from individuals and companies to develop projects using its resources. With an application form and requirement for personal consumables, the lab facilitates a broad range of projects.

Collaborative Calls: BioLab Lisbon organizes calls for projects that bring together diverse expertise, exploring themes for community enrichment and subsequently publishing or documenting the outcomes.

International Partnerships: The lab engages in national and international collaborations in microbiology, bio-art, bio-engineering, circular economy, and sustainability.Space management: The lab comprises an open area (BSL 0) of ~120m2 and a closed wet lab area (BSL1) of 12m2.

Security: All users must understand and sign a safety and ethics manual. Minors need guardian consent or accompaniment.

Initial Costs and Maintenance: The lab's initial setup costs included space adaptation, laboratory furniture, and equipment, totaling around €67,000. Ongoing costs include salaries for the staff, reagents, consumables, and short-lived goods.

Engagement with New Users: The lab actively engages with schools and diverse audiences through a comprehensive workshop program. These initiatives serve as a catalyst for fostering interest in science and encouraging laboratory experimentation.

Networking with Other Biolabs: While currently informal, BioLab Lisbon aims to establish a more formal network with other bio labs worldwide. This initiative will be spearheaded at the upcoming Vulca23 seminar, intending to connect Biolabs and bio-corners in fablabs and biohacking labs globally.

Notable projects: Biolab Lisboa has an astounding success rate in the short period time it has been in operation.
"Bio Packaging for e-commerce": A call for designers and biologists to develop solutions with mentoring.

Workshop Programs: Educational workshops on diverse topics.
"Caminho Efémero (Ephemeral Path)": A collaboration for creating bio-blocks in the city.
"Imperfecti": A startup for mycelium objects and tiles that began in the lab.
"Debris": A partnership for creating new materials, offering free lab access to students.
"Curriculo Lisboa": Integrating lab experiences into secondary school curricula.
Collaborations with the Design Department of Beaux Arts Faculty for biomaterials creation.

Open access policy

BioLab Lisbon's open access policy is central to its operations. The lab offers open days for project exploration and a more structured application process for in-depth project development. This flexible approach ensures that a wide range of projects align with the lab's mission.

Conclusion

Combining open access with a structured approach to safety, innovation, and community engagement BioLab Lisbon stands as a model for emerging bioFABLABS,. Its successful implementation and diverse range of projects demonstrate the potential of such labs to serve as hubs of creativity and learning in the realm of biodesign and sustainability.

More information about other BioLabs can also be seen at:
https://miro.com/app/board/uXjVN6lu0Qk=/
Be our guest to explore more!

THE CONCEPT OF OPEN ACCESS

The concept of the Open Access bioFABLAB is grounded in the idea of sharing, aligning it with the principles of the Sharing Economy and the Maker Movement.

> "Sharing is an alternative to the private ownership that is emphasised in both marketplace exchanges (...) [W]e may share a vacation home, a park bench, or a bag of jelly beans. We may also share more abstract things like knowledge, responsibility, or power. In each case, all of those involved in the sharing have something (a share) of the costs or benefits of a thing. (...) We can share not only places and things, but also (...) our ideas, values, and time" (Belk, 2007).

The sharing economy, the maker movement and the FABLAB community

The concept of the Sharing Economy envisions a transition towards a more interconnected and ultimately sustainable society. Prominent examples include bike and car-sharing services, peer-to-peer room rentals, gadget sharing, and clothes swapping initiatives. Inherently rooted in the idea of communal access to underutilised assets (Heinrichs, 2013), the Sharing Economy emphasises "access over ownership" (Curtis and Lehner, 2019). Consequently, through sharing, the overall consumption of new products can be reduced, positively impacting resource use and fostering a harmonious coexistence between individuals and their environment.

The Maker Movement or Maker Culture is described as a worldwide "creative revolution" and a "return to our artisanal past" (Hult News, 2013). Beyond traditional crafts and the activities like metalworking and woodworking, the Maker Movement is often associated with electronics, robotics and 3D printing. Pointed out by Wolf et al. (2014), the Maker Movement has three distinctive characteristics: (1) learning by doing, (2) transdisciplinarity, and (3) sharing and open access. The Maker Movement is based on open access to hardware and tools which makes it comparable to open-source software. An often-claimed characteristic of the maker movement is its strong commitment towards openness (Saari et al., 2021). The openness of the movement is embedded in the practice of sharing knowledge, ideas and designs. Similarly to the Sharing Economy, the Maker Movement is challenging the current production system which relies on intellectual property rights (Saari, et al., 2021).

FabLabs (fabrication laboratories) are one example of the Maker Movement (Wolf et al., 2014). By Gershenfeld (2005), FabLabs were described as "place[s] to make (almost) anything", based on open access, places where everybody can design, fabricate, test and innovate (Wolf et al., 2014). FabLab communities operate on principles of sharing, networking, collaboration, and open-source. A central aspect of the FabLab philosophy is the democratisation of technology; the accessibility of high-tech prototyping machines, ensuring that these tools are not limited to a selected few but are made available to "everyone" (Wolf et al., 2014).

Open access in biodesign and the DIYbio movement

The DIYBio Movement is defined as a biotechnological social movement in which individuals, communities, and small organisations with limited formal research training study biology using the same methods as traditional research institutions. According to the Hague Centre for Strategic Studies (2013), "the movement promotes the democratisation of science through home-grown innovative biological research". This democratisation is facilitated through the creation of diverse communities where individuals from various backgrounds come together, sharing knowledge and expertise. Courses and open sharing platforms are crucial for this exchange, while affordable lab spaces provide practical environments for prototyping (DITOs Consortium, 2019). In the field of biodesign, accessibility to labs is a critical factor, as many innovations are developed in spaces inaccessible to the public. Drivers of innovation in biodesign include knowledge hubs, educational initiatives, open sharing platforms, and affordable lab spaces that not only provide access to tools but also foster potential collaborations (DITOs Consortium, 2019). In the long and complex process of creating an innovative biodesign product, experimentation, countless testing and prototyping requires not only substantial resources, but also access to knowledge and ultimately to a well-equipped lab (DITOs Consortium, 2019). Innovation in the field of biodesign, linked to architecture and product design, generally developed by architects or designers with limited training in biology. Thus, lab spaces with transdisciplinary networks and open access to knowledge are essential to successful projects. All in all, only with the concept of open access, can innovation in biodesign become widespread.

Defining Open Access bioFABLAB

Open Access bioFABLAB represents a paradigm shift in the field of biodesign, embodying principles that reshape traditional research practices. Coworking laboratories, as described by DITOs Consortium (2019), "allow affordable space and instrumentation and access to a bigger network of partners for small start-ups and projects within biotechnology and biodesign to develop". A great example of a coworking laboratory is the London based Open Cell Labs designed for biotech and life sciences startups. It "aimed at making biotech and its endless possibilities for a better world, more open and accessible to everyone" (Open Cell Labs, n.d). Another example is the BioFabLab RUC, "an open laboratory, greenhouse and kitchen for prototyping with biological matter and materials at Roskilde University" (BioFabLab RUC, n.d). BioFabLab RUC provides open source hardware for science and laboratories "to prototype with living matter, and combine this with electronics, digital fabrication, robots and coding" (BioFabLab RUC, n.d). Based on the existing examples, at its essence, the Open Access bioFABLABrepresents (1) the sharing of science hardware, (2) the exchange of knowledge and expertise, (3) easy and safe access to laboratory spaces (4) and fundamentally, it prioritises inclusivity and social accessibility.

(1) Sharing of science hardware: Sharing science hardware involves collaborative use of laboratory equipment. Additionally, the Open Access bioFABLAB offers the potential for 3D printing scientific equipment, contributing to cost reduction. Ultimately, the Open Access bioFABLAB facilitates accessible prototyping opportunities.

(2) Exchange of knowledge and expertise: Beyond sharing hardware, knowledge and expertise sharing are crucial components of the Open Access bioFABLAB. Accessible knowledge dissemination through open academies, workshops, and sharing platforms fosters collaboration and generates new ideas. Furthermore, the Open Access bioFABLAB promotes transdisciplinary cooperation and knowledge exchange of diverse disciplines, making it accessible to a wider audience. Additionally, open access to scientific publications and research findings is important in spreading knowledge both within and beyond the scientific community.

(3) Easy and safe access to laboratory spaces: The Open Access bioFABLAB ensures easy and safe access to laboratory spaces. Easy access implies that the laboratory spaces are well-equipped and available for researchers as needed. The lab takes responsibility for safety measures, which are communicated directly with the researchers.

(4) Inclusivity and social accessibility: The Open Access bioFABLAB promotes inclusivity and social accessibility, offering affordable labs to a wide target audience, with low skill barriers to entry, and ensuring the availability of expert support.

Part II - framework

COCOON'S CONCEPT PERSPECTIVE

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In the CoCoon project, we want to set a common ground for organisations to begin experimenting with biodesign. This document outlines the tools, infrastructures and policies needed to establish a bioFabLab. Be mindful that the information builds on deliverable 2.2, which map's optimal methods for mainstreaming biodesign. These two deliverables give designers enough information to start experimenting. Our forthcoming deliverable, 3.1 'Seeds of Change,' will detail biodesign methods in a recipe-like format, enabling replication and innovation using the infrastructure layed out here.

The DIY Kitchen Lab

As the DIY Biodesign movement started in the home kitchen, it is only appropriate to begin our framing of the Bio Fab Lab from there. The most straightforward step for Fab Labs and, in fact, any organisation or school to expand into bio design would be to have a designated kitchen area for bio design exploration. Here, you will find all the tools you know and love from a regular kitchen. All the big kitchen equipment is here: a refrigerator, oven, stove, microwave, and dishwasher. On the counter, there is a mixer, blender, scale and pressure cooker. In the drawers, you will find what you expect in a kitchen: spatulas, scissors, knives, pots, pans and heat proof oven containers. The cupboard is filled with glassware, mason jars and some glass cylinders that may slightly deviate from the average kitchen.

However, the ingredients are different, and sanitation rules are much higher. This kitchen has a strict no-eating rule; only the organisms we work with get nourishment. This is important: eating and cross-contamination are sure ways to mix a recipe of disaster.

Some ingredients you will use are commonly found in a kitchen but are often thrown away, such as fruit peels, coffee grinds, olive pits, and eggshells. The typical dry ingredients are emulsifiers, such as pectin, used to make jam, and thickening agents like corn starch.

- **DIY Bio Essential**

Equipment

Tools: Spatulas, scissors, knives, glassware, mason jars, glass cylinders, metal spatula.
Cookware: Pots, pans, heat proof oven containers.
Appliances: Mixer, blender, kettle, pressure cooker, refrigerator, freezer, oven, stove, microwave, sink, dishwasher, ice machine.
Measuring Tools: Cups, scales, syringes, pipettes.

Ingredients

Waste Products: Fruit peels, coffee grinds, olive pits, eggshells, paper.
Dry Ingredients: Emulsifiers like pectin, agar-agar, corn starch, salt and baking powder.
Sanitation: Isopropanol.
Organisms: Based on project, SCOBY, oyster mushroom, algae, moss.

• In the Spirit of Innovation and Sustainability

In the DIY Bio Kitchen, we blend everyday cooking methods with the excitement of scientific discovery. It's a space not just for creation but for reimagining what's often discarded. Utilising waste products and common ingredients in innovative ways, we're pushing the boundaries of biodesign while contributing to a more sustainable future.

• Begin Your Biodesign Journey

- **Start simple with Kombucha leather using SCOBY**
- **Explore the potential of mycelium for biodegradable alternatives to styrofoam**
- **Dive into the world of biofilms with algae**
- **Turn food waste into useful bioplastics**
- **Experiment with bio-foam derived from wood pulp**
- **Discover how to grow textiles from herbs**
- **Cultivate your own salt crystals**

As you embark on this journey, remember that the principles and processes you learn here can also be applied in any home kitchen and can expand with increased knowledge and facilities. The online DIY bio movement offers a wealth of information to guide you. Begin with something as straightforward as Kombucha and gradually work your way through more complex projects. Each step you take is a stride towards mastering the art of biodesign.

Let your curiosity lead the way in this unique kitchen, where science meets sustainability. Your creations here have the power to inspire change and showcase the potential of biodesign. So, roll up your sleeves, gather your ingredients, and let the magic of DIY bio unfold!

The bioFABLAB

The bioFabLab is intended for organisations with robust infrastructure that want to adopt more sustainable practices or amplify their innovation capabilities with biodesign. Transitioning from the kitchen, the bioFABLAB allows for the expansion into more complex Biodesign areas. In the home kitchen, all of the basics of biodesign can be achieved. But to expand further into complex biodesign areas, more specialised equipment is needed. For organisations with a Fab Lab and a biology department, this may be easily achieved by slightly reorganising the placement of tools or classrooms. The space is set up to fulfil BSL level 1, which means we are working with living organisms that are not harmful to humans.

To fully realise this, the Fab Lab or maker space needs to be supplemented with essential kitchen and biology classroom equipment, including a bunsen burner, microscopes, an incubator, an autoclave, and necessary biohazardous waste disposal. Freezers (-20°C and -80°C), a biosafety cabinet, and a laminar flow hood are crucial for bacteria-related work. To shift from experimentation to fabrication basic Fab Lab tools like 3D printers, CNC milling machines, electronics, lasers, and vinyl cutters should be readily accessible.

To enrich fabrication methods with biology, we will merge three recognised learning environments to create a bioFABLAB.

- **DIY bio:** Essential kitchen tools for basic biodesign processes, fostering a familiar and accessible starting point.

- **Fab Lab Technology:** Advanced tools for intricate and scalable designs. 3D printers, CNC machines.

- **Bio Lab:** Precision equipment from biology classrooms. Bunsen burners, microscopes. incubators, and more, introducing precision and control in working with living organisms.

• bioFABLAB Tools and Spaces

The bioFABLAB space, spanning approximately 45 - 55 m2, is ideal for group activities like classes and workshops. A smaller space of around 16 m2 suffices for individual prototyping. Four main components, along with access to a Fab Lab or Maker space, are essential. In our Framework simple layouts with the necessary tools of a BioFabLab can be found. The four main components are the following:

- **SAFE** zone
- **PREP** zone
- **WORK** zone
- **GROW** zone

The **SAFE** zone.
Personal sanitation space is necessary to have at the entrance. This is the area everyone goes through, so this is the area you use to avoid contaminants from entering or leaving the lab. There will be lab coats, gloves, and security glasses (hair bands are a nice feature). This is the first area people interact with, so it is a wise space to store the first aid kit and emergency equipment here. As unwanted contaminants can be transmitted on clothes, lab coats are a safety measure to prevent anything from leaving or entering the bioFabLab. Contaminants can infect the designs and ruin experiments. Therefore, everyone wears a lab coat, and the lab coats never leave the room.

The **PREP** zone:
The hub for preparing design ingredients, for the designs is the most active zone, and there will be a lot of blending and grinding, boiling, measuring, and mixing. Featuring all the elements from DIY BIO plus, to protect the organisms you are working with, there is a water purifier and a pH metre in this space. Instead of a pressure cooker, there will be an autoclave. There will also be a bunsen burner and a laminar flow cabinet to create contaminant-free environments to work with living organisms.

The **WORK** zone:
Mirroring a biology classroom, it includes a microscope, heating plate, dehumidifier, humidifier, heater, Petri dishes, and recommended air pumps, irrigation systems, and liquid pumps. Advanced tools like a water bath, centrifuge, and fume hood are optional but beneficial.

The **GROW** zone:
Designed to nurture living designs without contamination. Key elements include a locked cabinet with glass for monitoring, grow lights, and adjustable heat and moisture controls. An incubator ensures optimal conditions for organisms.

• **Sustainability and Discovery**

The bioFabLab infrastructure enables the implementation of all biodesign methods detailed in CoCoon's deliverables. However fabrication in the bioFABLAB is not just about replicating existing recipes; ;it is a space to iterate methods from others and uncover new solutions, new methods, and new possibilities that align with our vision for a sustainable future. Sharing these innovations with the maker and designer community can accelerate biodesign's transition into mainstream applications.

The bioFABLAB, it's a platform for new discoveries, contributing to a sustainable future. Here design, biology and technology are intertwined, fostering a collaborative environment for groundbreaking explorations.

• **Open Access bio FABLAB Safety**

Safety extends beyond mere compliance with regulations, it encompasses proactive measures that anticipate potential risks associated with biodesign activities conducted within open-access spaces. The goal of safety in bioFABLAB should not only be to protect individuals directly involved but also to prevent any accidental impact on surrounding communities or ecosystems.

We advise beginners handling microorganisms to work with experienced individuals until they both feel confident about working independently. Gaining proficiency in handling microbes often requires time and training.

Before initiating lab activities, participants and facilitators must thoroughly familiarise themselves with proper biosafety protocols and lab practises (Barker, 2004). The **Community Biology Biosafety Handbook** (Armendariz, et al., 2020) serves as an essential guide in this regard along with the **CHEMARTS Cookbook** (Kääriäinen, et al., 2020) and the **Laboratory biosafety manual** (World Health Organisation, 2020). Guidelines laid out by the University of Utah are also an important resource for teachers and mentors intent on instructing groups in biolabs (2021). These cover many topics, from personal protective equipment to waste management, ensuring a holistic approach to safety.

Clothing: Lab coats, gloves, and safety glasses are essential PPE for lab users. Ensure clothing is secure and non-flammable, covering skin fully (avoid shorts or short skirts). Wear closed, flat shoes, tie back long hair, and avoid long or dangling jewellery or scarves that could snag or tangle. Remove rings that might puncture gloves.

• **Emergency Equipment**

• First aid kit, fire extinguisher(s) and fire blanket(s)

• Chemical and Biological spill kit (see details in the Community Biology Biosafety Handbook (Armendariz, et al., 2020))

• **Necessary infrastructures**

- **Ventilation:** Ensure a flow of air to maintain a safe and comfortable working environment.
- **Plumbing:** Ensure the room has a sink and proper drainage.
- **Gas lines:** A bunsen burner does require gas, consider how to install it.

Waste Management: If affordable, consider investing in a professional bio waste pickup service for biosafety. Regular cleaning events help maintain lab tidiness. Train volunteers and members in trash disposal and general cleanup by integrating these practices into routine tasks. Also, keep a simple chemical and biological spill kit in the lab.

Standard Operating Procedures (SOP's): Detailed guidelines of best practices, describing the steps to safely and efficiently conduct laboratory procedures and equipment, consistent with each institution or space.

Signage and Labelling _ Essential for lab safety, signs and labels should cover:

- Storage and emergency contact information.
- Cleaning and equipment operation instructions.
- Safety special equipment warnings (e.g., hot surfaces, pressure, hazardous chemicals etc.).
- Emergency exits and fire extinguishers.
- Label all chemicals and biological materials, following guidelines in the Community Biology Biosafety Handbook (Armendariz, et al., 2020) on Chemical and Biological Safety.

• **Essential Laboratory Equipment**

When setting up a laboratory, it's crucial to have a comprehensive understanding of the essential equipment needed to facilitate various scientific investigations. The following list includes fundamental and advanced equipment for a well-functioning lab. This compilation is not exhaustive; the specific needs will vary depending on the nature of the experiments conducted. However, it provides a solid foundation for those looking to establish a lab, particularly in biology, chemistry, or material science. We recommend anyone setting up a lab thoroughly familiarise themselves with these tools and consider their relevance to their research needs.

• **Safety equipment**

Biohazard Waste Disposal: Containers and systems for the safe disposal of biohazardous materials.
Chemical and Biological Spill Kit: Equipment and materials to contain and clean up hazardous spills.
Fire Alarm: Alert system for the immediate notification of fire to ensure prompt evacuation and response.
Fire Extinguisher: Portable devices for extinguishing small fires quickly.
First Aid Kit: Supplies and medications for emergency medical treatment.
Lab Coats: Protective garments designed to shield the wearer's body from hazardous substances.
Latex Gloves: Disposable gloves to protect hands from contaminants and chemicals.
Safety Cabinet: Storage for flammable, corrosive, or toxic substances to prevent accidents and exposures.
Safety Glasses: Eye protection to shield against chemical splashes, flying debris, and other hazards.
Safety Shower and EyeWash Station: Emergency shower and eye flushing equipment to mitigate exposure to hazardous substances.

- **Core Biofabrication equipment**

-20°C Freezers: For general laboratory storage at standard freezing temperatures.

Air Pumps: For aerating samples, promoting the growth of microorganisms or aquatic samples.

Autoclave: For sterilising equipment and supplies with high-pressure saturated steam.

Biohazard Waste Disposal: For the safe disposal of biohazardous materials.

Blender: For mixing or emulsifying substances in the lab.

Bunsen Burner: Provides a single open gas flame, used for sterilisation.

Dehumidifier/Humidifier: For controlling the humidity level in the lab.

Dishwasher: For cleaning glassware and other reusable lab equipment.

Glassware: Includes beakers, flasks, test tubes, and more.

Grow Cabinets: For cultivating plants or other organisms under controlled conditions.

Grow Light: For providing artificial light for plant growth and controlled light experiments.

Hand Tools: Include screwdrivers, pliers, scissors, etc.

Heater: For maintaining a warm environment or heating specific areas in the lab.

Ice Machine: For providing ice for experiments requiring temperature control.

Incubator: For providing controlled environments for the growth of cultures.

Irrigation System/Liquid Pumps: For controlled watering/liquid media feeding in experiments.

Kettle: For boiling water, often necessary for various lab procedures.

Kitchen Equipment: Metal tools for preparing samples or reagents, spoons, knives, spatula.

Measuring Cylinder: For accurately measuring volumes of liquid.

Microscope: For viewing objects too small for the naked eye.

Microwave: For quick heating of reagents or samples.

Mixer: For mixing substances in the lab.

Office Supplies: Separate supply for the lab to avoid contamination.

Oven: For drying or sterilising equipment and samples.

Petri Dishes: For culturing cells and bacteria.

pH Meter: For measuring the acidity or alkalinity of solutions.

Pipette: For transferring or measuring small amounts of liquid.

Refrigerator: For storing chemicals, biological samples, or reagents at low temperatures.

Scale: For accurately measuring the weight of various substances.

Shaker: For mixing solutions or agitating samples.

Silicone Moulds: For casting and shaping materials.

Sink: Essential for disposing of liquids and for cleaning lab equipment.

Stove: For heating and sterilisation purposes, if not using a heating plate.

Water Purifier: For removing impurities from water for laboratory use.

Work Bench: A sturdy table providing a stable, flat surface for experiments.

• Advanced bioFabLab Equipment:

If you intend to work with more complex processes that require specific tools to assist in the work the following equipment is essential:

-80°C Freezers: For long-term storage of critical biological samples, such as RNA, DNA, and certain cell types.
Centrifuge: For separating components of a liquid or fluid based on density by spinning samples at high speed.
Freeze Dryer: For removing moisture from samples through sublimation, preserving them for long-term storage.
Fume Hood: A ventilated enclosure that extracts hazardous fumes, vapours, and dust to protect laboratory personnel.
Heating Plate: An electrically heated surface for heating and ensuring uniform temperature across samples.
Magnetic Stirrer: For stirring solutions, promoting even mixing without the need for a manual stirring device.
Sonicator: For using high-frequency sound waves to disrupt cells, mix solutions, or speed up chemical reactions.
Spectrophotometer: For measuring the intensity of light wavelengths absorbed by a sample, used for quantitative analysis in biochemistry and molecular biology.
Water Bath: A container filled with heated water used to incubate samples at a constant temperature over an extended period.

• Advanced fabrication tools for biodesign

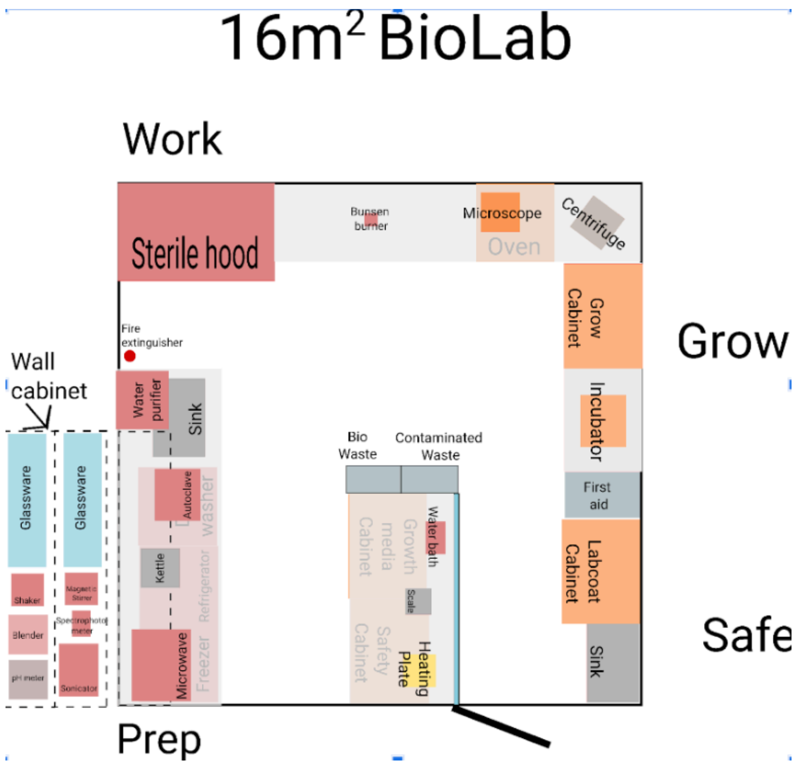
A few fabrication tools not part of the fab lab inventory have been especially helpful for biodesign. We want to include them here as they can significantly advance the lab's capabilities:

Clay 3d printer: To experiment with extruding different materials, and printing surfaces for organisms to grow such as moss.
Vacuum Former: To create moulds for designs to grow in, works best when accompanied with a 3d printer.
Waterjet Cutter: To cut stainless steel and glass that can withstand autoclaving as materials to make custom made equipment and apparatuses.

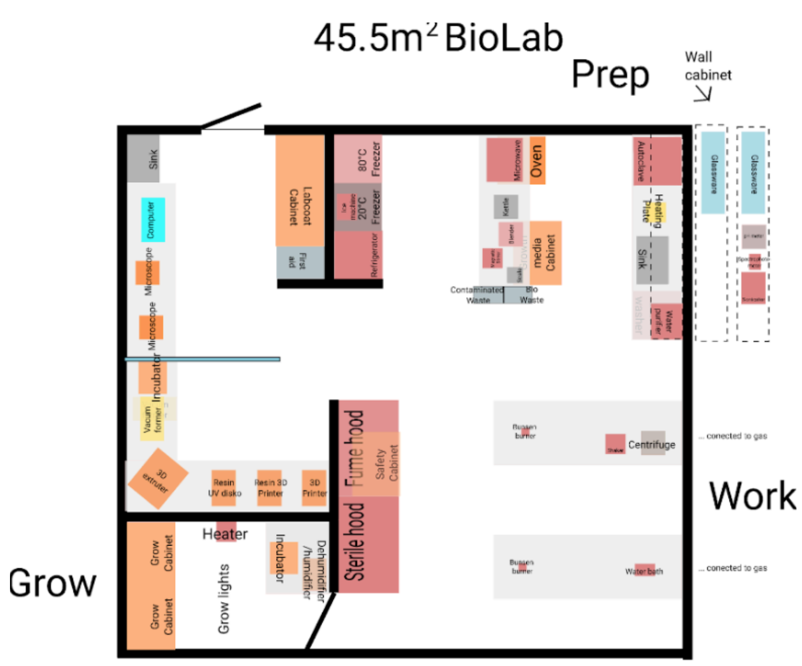
• **bioFABLAB Layouts**

These layouts are organised as 16, 45 and 55 m2 spaces, the smallest space supporting individual prototyping for up to 2 entrepreneurs working together simultaneously. The larger spaces are large enough to support group work, for groups of 7 -15 respectively. These designs will be reiterated further with the Bio Design community throughout the CoCoon project. For further information or comments on the design please contact Thora Oskarsdottir via email: thora@flr.is

The 16 m2 prototyping bioFABLAB
Intended for prototyping and teaching groups of up to 3 students

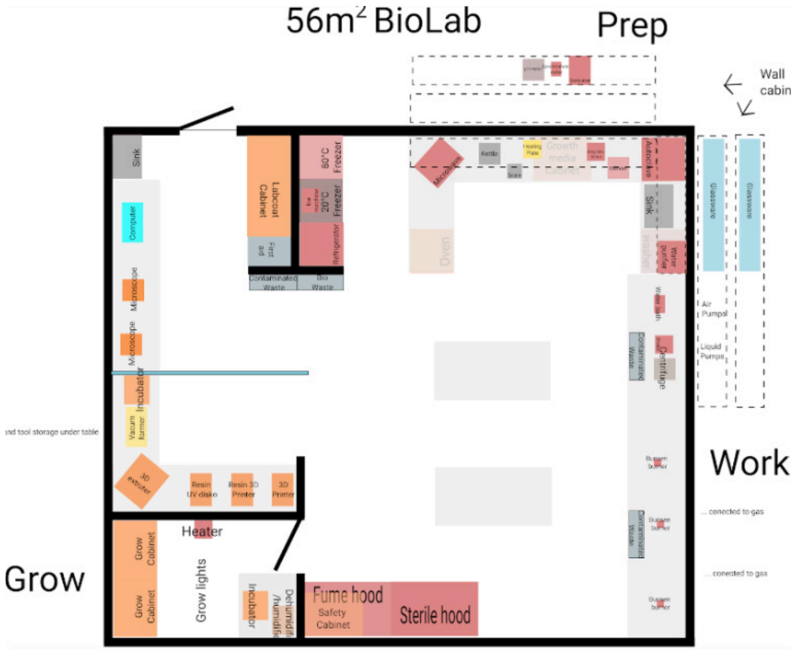


The 45m2 bioFABLAB
Intended for prototyping and teaching groups of up to 7 students



The 55m2 bioFABLAB

Intended for prototyping and teaching groups of up to 15 students



BALANCING OPEN ACCESS AND SAFETY POLICIES TO CREATE A bioFABLAB

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We anticipate that balancing open access with safety in a bioFABLAB will be a delicate task. Laboratory directors and staff must navigate the complexities of fostering a collaborative, educational environment while mitigating the inherent risks associated with cultivating living organisms. Establishing clear guidelines on permissible activities in the lab is crucial, but it's equally important to maintain a practical perspective on the lab's overarching goals, especially when the aim is to educate and engage newcomers in the field.

Easy access to the bioFABLAB is essential to foster innovation, especially in educational settings. This aligns with the Fab Charter's principles of global collaboration and providing access to digital fabrication tools. The World Health Organization (WHO) has been a guiding force in biosafety, with its Laboratory Biosafety Manual (LBM) advocating for a risk-based, technology-neutral, and cost-effective approach to biosafety. This approach resonates with the Fab Charter's emphasis on operational, educational, and technical support, ensuring safety and responsibility in the lab. The LBM advocates for laboratory facilities, safety equipment, and work practices that are relevant, proportionate, and sustainable on a local level. The WHO's LBM advises that establishing a lab working with biological agents begins with a comprehensive risk assessment, which includes information gathering, risk evaluation, developing a risk control strategy, and implementing risk control measures. This process is dynamic, adapting as new information arises.

The LBM categorises biosafety into four levels (BSL1 to BSL4), with BSL1 being the least strict. In the context of a fab lab, it's essential to tailor the lab's function to its intended use, ensuring that activities align with both the lab's purpose and national regulations. For instance, a bio-lab focused on demonstrating the use of organic waste or cultivating fungi for new materials might not require strict adherence to biosafety levels, though compliance with national guidelines remains imperative.

The Cocoon Project's Open Access bioFABLAB Concept recommends to develop work at biosafety level 1 (BSL-1), meaning the manipulation of non-hazardous bio materials, complying with European directive 2000/54/EC (EU, 2020, 2021). According to this directive, "group 1 biological agent means one that is unlikely to cause human disease" (EU, 2020).

Under this goal, the biological agents manipulated must be known to be harmless, and it should be explained to anyone working or in contact with the materials about the basic safety measures to avoid allergies or other low-risk harms related to the manipulation and processing of the materials at the lab. The required safety equipment, such as protective goggles, masks, gloves, sanitising agents, and work coats should be available and recommended to all participants, according to the use. Special attention should be taken with suspended particles resulting from sanding and machining processes which may require attention and the use of protective measures.

According to the Wikipedia definition of BSL-1 (Wikipedia, s.d.), [2] "Biosafety level 1 (BSL-1) is suitable for work with well-characterised agents which do not cause disease in healthy humans. In general, these agents should pose minimal potential hazard to laboratory personnel and the environment. At this level, precautions are limited relative to other levels. Laboratory personnel must wash their hands upon entering and exiting the lab. Research with these agents may be performed on standard open laboratory benches without the use of special containment equipment. However, eating and drinking are generally prohibited in laboratory areas. Potentially infectious material must be decontaminated before disposal, either by adding a chemical such as bleach or isopropanol or by packaging for decontamination elsewhere. Personal protective equipment is only required for circumstances where personnel might be exposed to hazardous material. BSL-1 laboratories must have a door which can be closed to limit access to the lab. However, it is not necessary for BSL-1 labs to be isolated from the general building.

This level of biosafety is appropriate for work with several kinds of microorganisms including non-pathogenic strains of Escherichia coli and Staphylococcus, Bacillus subtilis, Saccharomyces cerevisiae, and other organisms not suspected to contribute to human disease. Due to the relative ease and safety of maintaining a BSL-1 laboratory, these are the types of laboratories generally used as teaching spaces for high schools and colleges."

Open Access

The Erasmus+ Programme has its own policy of safety and Open Access, available online (EU, n.d.). Such materials are known as 'Open Educational Resources' (OER). Complying with these directives, all deliverables, toolkits, and learning resources of the Cocoon Project are public and freely available for the public under an open licence through the project website (www.cocoon.bio). Those materials are licensable through a Creative Commons Share-Alike 4.0 International rights (Creative Commons, s.d.), meaning that you are free to:

> **Share -** copy and redistribute the material in any medium or format for any purpose, even commercially.
> **Adapt -** remix, transform, and build upon the material for any purpose, even commercially. (Creative Commons, s.d.)

This should comply with the following terms:

Attribution - You must give appropriate credit, provide a link to the licence, and indicate if changes were made. You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use.

ShareAlike - If you remix, transform, or build upon the material, you must distribute your contributions under the same licence as the original.

No additional restrictions - You may not apply legal terms or technological measures that legally restrict others from doing anything the licence permits. (Creative Commons, s.d.)

In the realm of scientific research, an open-access bioFABLAB should build on transparency and collaboration for sustainable development.

[2] https://en.wikipedia.org/wiki/Biosafety_level (retrieved 1.12.2023)

Towards a bioFABLAB Charter

An open-access bio-lab in the context of scientific research typically refers to a facility or environment that promotes transparency, collaboration, and unrestricted access to its resources, data, methodologies, and findings. Several key characteristics define an open-access lab:

Transparency: Open access to research materials, methodologies, and data to eliminate information barriers.
Accessible Resources: Provision of datasets, protocols, equipment, and workshop facilities to the wider community.
Open Publication: Sharing research findings freely through journals, preprint servers, or repositories like GitHub.
Community Engagement: Encouraging collaboration and discussion through conferences, workshops, and online platforms.
Licensing and Intellectual Property: Employing clear, permissive licensing strategies for the lab's work.
Ethical Oversight and Compliance: Adherence to ethical guidelines and regulatory standards.
Diverse Collaboration: Fostering interdisciplinary problem-solving and innovation.
Technology and Platforms: Using platforms like GitHub for data and methodology sharing.

The Fablab network, established with open-access principles, embodies these values. The Fab Charter, published in 2012, by MIT's Center for Bits and Atoms, outlines principles including global collaboration, sharing resources and knowledge, operational and educational support, community access, safety and responsibility, intellectual property rights, and commercial activity guidelines.

The Fab Charter

What is a fab lab?
Fab labs are a global network of local labs, enabling invention by providing access to tools for digital fabrication.

What's in a fab lab?
Fab labs share an evolving inventory of core capabilities to make (almost) anything, allowing people and projects to be shared.

What does the fab lab network provide?
Operational, educational, technical, financial, and logistical assistance beyond what's available within one lab.

Who can use a fab lab?
Fab labs are available as a community resource, offering open access for individuals as well as scheduled access for programs.

What are your responsibilities?
safety: not hurting people or machines
operations: assisting with cleaning, maintaining, and improving the lab
knowledge: contributing to documentation and instruction.

Who owns fab lab inventions?
Designs and processes developed in fab labs can be protected and sold however an inventor chooses, but should remain available for individuals to use and learn from.

How can businesses use a fab lab?
Commercial activities can be prototyped and incubated in a fab lab, but they must not conflict with other uses, they should grow beyond rather than within the lab, and they are expected to benefit the inventors, labs, and networks that contribute to their success.

Incorporating these principles, the bioFABLAB should operate with transparency, providing open access to research materials, methodologies, and data. This approach promotes diverse collaboration and innovation, as highlighted in the Fab Charter. Additionally, the Fab Charter's focus on community engagement and ethical oversight is mirrored in the bioFABLAB's commitment to open publication and adherence to ethical standards.

Thus, adopting and adapting the principles of the Fab Charter is vital for the bioFABLAB concept. Displaying a visible charter in the lab, similar to those in Fablabs, would underscore the lab's commitment to open access, safety, and innovation, fostering an environment where creativity and scientific inquiry can thrive in harmony with safety and accessibility.

NURTURING BIODESIGN - WORKING WITH ORGANISMS

The following chapter provides an overview of the selected organisms and projects a bioFABLAB can allow institutions to explore. To effectively begin working with each organism, it's crucial to understand and prepare the necessary equipment and tools. This includes identifying specific equipment and tools tailored to the organism you're dealing with. For instance, working with bacteria might require different equipment compared to dealing with plants or moss.

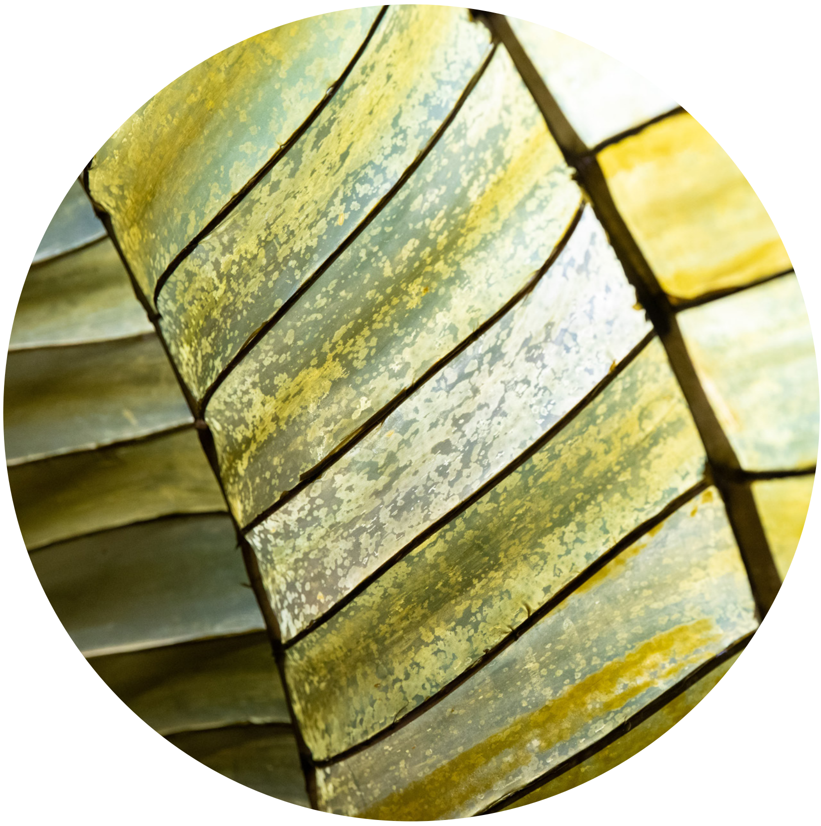
Equally important is establishing the right environmental conditions. This involves ensuring the optimal temperature, humidity, light, and other factors specific to each organism. For example, cultivating fungi will have different environmental needs than growing algae.

Furthermore, an understanding of the process for extracting material from these organisms is vital. This includes knowing the techniques and equipment for extraction, which vary depending on the organism and the type of material needed.

Additionally, ensuring safety and proper disposal methods is paramount. This encompasses using protective gear, understanding the potential hazards associated with each organism, and adhering to protocols for disposing of waste and contaminated materials. It's essential to be well-versed in these safety procedures to maintain a safe and efficient working environment.

ORGANISMS

A selection of innovative projects



BACTERIA

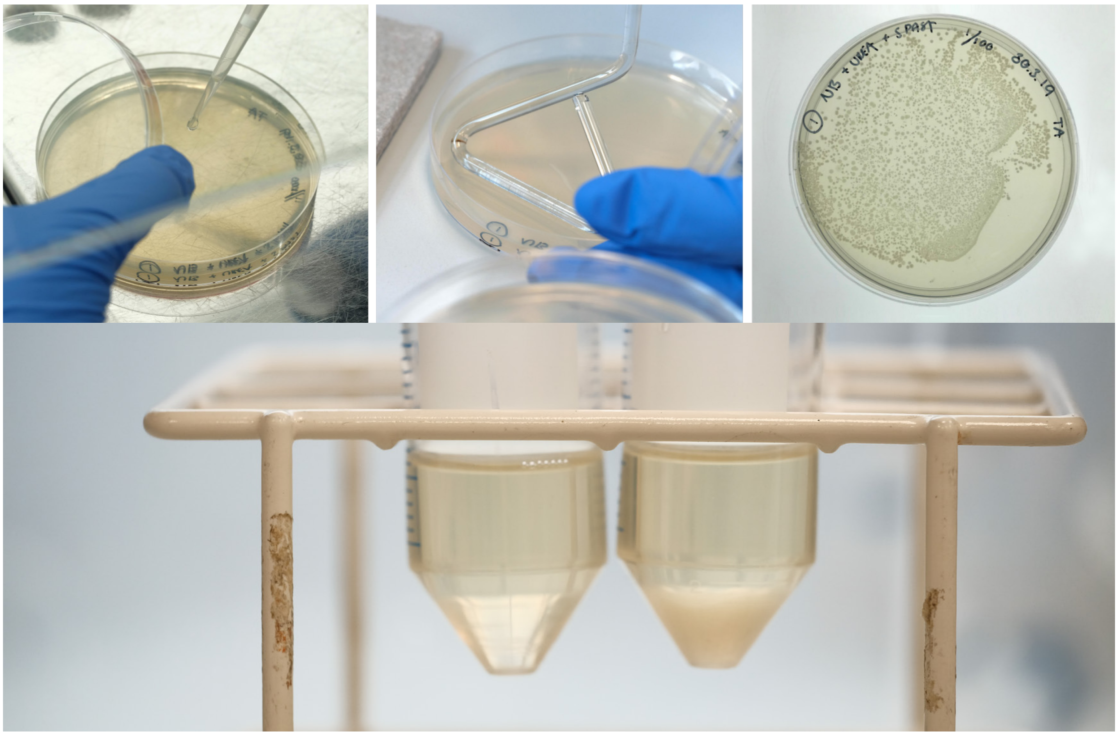
Organism

Bacterial cellulose: Acetobacter, Sarcina ventriculi and Agrobacterium
Textile Dyeing: Janthinobacterium Lividum and Serratia Marcenses
Bioluminescence: Photobacterium kishitanni and Vibrio fisherii
Biomineralization: Sporosarcina pasteurii

Projects

Pigment production
2D patterning
Construction materials
Leather-like materials

Images



Visual representation of bacteria growing on solid media and in liquid media. @Thora H Arnardottir

Equipment/Tools

- Sterile Work stations
- Lab coats
- Sealable containers/ glassware
- Autoclave/pressure cooker
- Bunsen burner or a sterile hood (laminar flow)
- Incubator
- Fridge and freezer
- Balancer/scale
- pH meter
- Bins for waste
- Sharps bin

For more complex work these can be added:

- Pipettes, etc.
- Hotplate stirrer
- Vortexes
- Pumps (peristaltic and air)
- Centrifuge

And much, much more....

Materials	• Distilled water • Disinfectant (e.g. 70% ethanol) • Plastic syringes, petri plates, loops • Parafilm • Disposable gloves • Paper towels • Falcon tubes • Autoclave tape • Sterile filters • Disposable bags
Environment	Bacteria grow at different temperatures and their environment can be controlled in incubators, many thrive in temperatures of around 30C.
Safety and containment	It's important to work in a sterile condition over a bunsen burner or in a flow cabinet to minimise risk of contamination. Sanitise materials and equipment before beginning work. Clean work areas both before and after handling microorganisms. Practice hand hygiene before and after any lab activity.
Disposal	Liquid and solid media might pose a risk to the environment and should be made inert through disinfection or autoclaving before discharging.
Extra Notes!	Make sure that the bacteria you are working with is a non-pathogenic species or in the Biosafety Level (BSL) 1 Laboratory. Working with human pathogens requires a BSL-2 laboratory or higher, as it falls outside the scope of a BSL-1 lab. Often, safer alternatives, like lab strains of E. coli, can be used instead of more hazardous ones.

FUNGI

Organism

Various (common) strains of fungi for mycelium growth
• Oyster mushrooms Pleurotus ostreatus
• Enoki Flammulina filiformis
• Shiitake Lentinula edodes
• Reishi Ganoderma lingzhi
• Lion's mane Hericium erinaceus

Projects

Grow furniture
Compostable packaging
Grow leatherlike textiles
Construction materials

Images


Visual representation of mycelium growing on agar and on straw pellets substrate. ©Ena Naito

Equipment/Tools

• Sealable container & breathable tape / grow bag
• Disposable gloves
• Oven
• Drying rack
• Sterilisation

Materials

• Mushroom spores
• Substrate - provides necessary nutrients for mycelium
  › Choice of substrate influences qualities of the resulting material. Can be retrieved from agricultural/textile waste streams (local substrate readily available - fresh coffee grounds, saw dust, straw pellets, wood chips, flax, cotton fibres, etc)
• Boiling water
• Disinfection medium (e.g. 70% ethanol)

Environment

• Mycelium culture needs to be maintained in controlled temperature, moisture, and light conditions.
  › Mycelium requires a warm and humid environment to develop. Optimal conditions vary according to strain, but most species prefer temperature around 25-35C, and 60-65% humidity.
  › Dark environment is preferable for rapid growth and preventing fruiting bodies. For fruiting bodies (mushrooms) to grow, exposure to sunlight will be needed.
• Leaving mycelium to dry at room temperature will put material to hibernated state - this would preserve the possibility of future growth.

Containment safety

Mycelium is especially prone to contamination, and proper sterilisation is of utmost importance.
Make sure to disinfect substrate and container before using. Work in a sterile area.

Use appropriate protective equipment, including laboratory coats, safety goggles, and protective gloves.
Before using any chemicals, familiarise yourself with the MSDS sheets.

Disposal

• Small quantities can be bio composted
• Large quantities, spores, and mycelium materials which might pose a risk to the environment have to be made inert through disinfection, sterilisation, or incineration before discharge to the environment.
› Drying mycelium at min. temperature of 60C

Extra Notes!

Various techniques for growing mycelium:

1- From living tissue of fresh mushroom
2- Mycelium spawn (most common)
3- Liquid culture inoculation and fermentation (injecting mycelium into liquid medium)

Where to start: Oyster mushrooms are the optimal choice to start your biodesign journey. They are a highly resilient mushroom, and popular within the biodesign community. Therefore a lot of resources and expertise can be found online to power your explorations.

TREES

Organism

Wood-based cellulose derivatives

Projects

Bio foams
Cellulose bioplastic film
Cellulose leather
Papermaking
Lignin dye

Imagens

Various materials with wood-based cellulose derivatives ©Ena Naito, DipWrap

Equipment/Tools

- Hand blender (with beater blade)
- Bowl
- Spoon/spatula
- Mould/drying surface
- Scale
- (Oven)
- Metal spatula

Materials

- Pulp (pulp sheets, recycled paper)
- Water
- Surfactant (washing detergent - for foaming)
- MCC (microcrystalline cellulose)
- NFC (nanofibrillated cellulose)
- CMC (carboxymethyl cellulose)
    - › Must be completely dissolved in water and air bubbles must be removed (by leaving overnight, or with a vacuum chamber)
- Glycerol (for flexibility)

Environment

Drying wood-based materials usually takes several days at room temperature. For a faster drying time, use an oven (50 - 60 degrees).

Containment and safety

Use appropriate protective equipment, including laboratory coats, safety goggles, and protective gloves.
Before using chemicals, familiarise yourself with the MSDS sheets.

Disposal

- Bio-composting
- If other additives are used and mixed with original ingredients, then the materials should be disposed according to the instructions and safety precautions

Extra Notes!

Note: only one drop of surfactant needed for foaming
CMC (also known as cellulose gum), and can be sourced commercially as a food-grade product
Some cellulose derivatives (MCC, NFC) must be stored in refrigerated environments to avoid moulding.

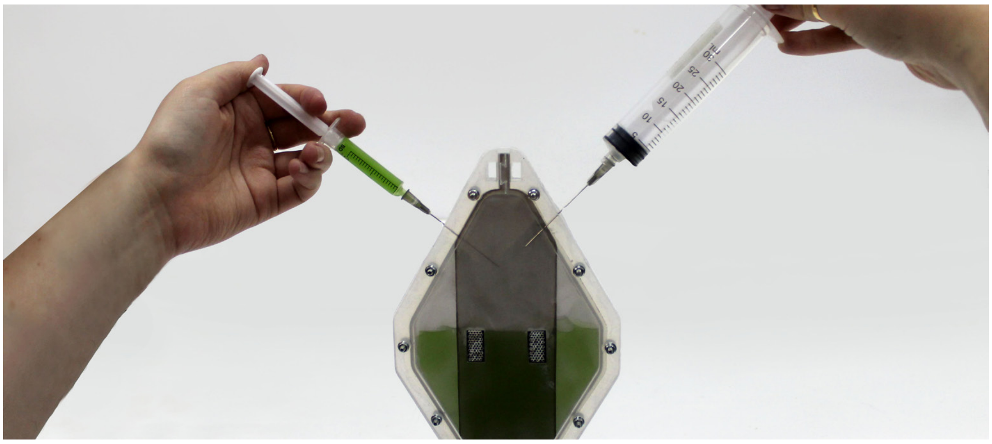
ALGAE

Organism — Brown, red or green marine algae such as kelp, dulse, dabberlocks, wracks and other seaweed species.

Projects — Bioplastics
Biophotovoltaics
Construction materials
Leather-like materials

Images

Various materials with cellulose derivatives Corpus Maris II by Julia Lohmann, 2022/2023 ©photo by Juhani Tenhunen



Biophotovoltaic panel injected with living algae culture. BioCatalytic Cell. ©photo by Thora H Arnardottir

Equipment/Tools — Algae are suitable for dyeing, "embossing, pressing, tanning, cutting, sewing, glueing, branding, embellishing, painting, punching, laser-cutting, lacquering, imprinting, moulding" (Lohmann, 2017).

All equipment and tools listed are therefore suggestions and will depend on the method used for any given objective. This list is non-exhaustive and experimentation with further tools encouraged.

- Sink/wash basin or tub
- Water
- Towels or paper towels
- Cutter/knife or scissors
- Blender
- Stove and pots
- Spoon and spatula
- Sewing kit (needles & thread)
- Space for drying/dehydrator
- Rack or frame
- Laser-cutter

etc.

Materials

- Freshly harvested or dried seaweed
- Agar agar
- Sodium alginate
- Optional: natural humectant such as glycerol to maintain the flexibility of the material

Environment	As seaweed is slimy and slippery, rinsing and drying off the material will make it easier to work with. Light, heat and humidity levels will affect changes in colour and textural qualities (e.g. drying algae completely will reduce its flexibility and make it brittle).
Containment and safety.	Seaweed is a natural and non-harmful material that is safe to work with. Use appropriate protective equipment, including laboratory coats, safety goggles, and protective gloves. Before using any chemicals, familiarise yourself with the MSDS sheets.
Disposal	• Composting/ natural decomposition • If additives are used, then the materials should be disposed according to the instructions and safety precautions
Extra Notes!	As with many natural materials that contain moisture, the seaweed will start to disintegrate and decay if left in its natural state. For optimal results, it is preferable to dry the material in single layers in a way that allows proper air circulation.

HERBS

Organism

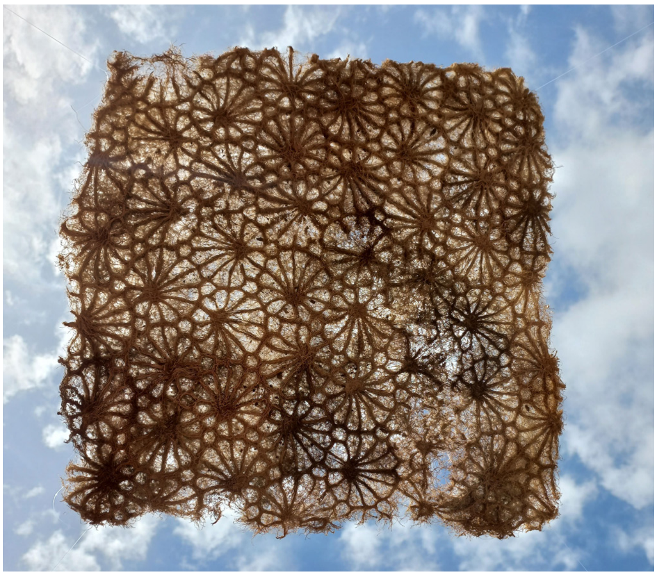
A wide variety of herbs and flowers can be used such as:

Wheatgrass, mints, potus

Projects

Growing textiles
Foams
Construction materials
Biophotovoltaics

Images



©Advanced Architecture Group, RootSkin

©Advanced Architecture Group, Floravoltaica

Equipment/Tools

- Sensors for monitoring temperature and humidity levels
- Irrigation system
- Drainage system
- Hand Trowel
- Watering can/hose
- Gloves
- Pots/planters with drainage holes (to avoid root rot and excess water)
- Humidifier
- Scissors for pruning
- pH tester

Materials	• Soil • Perlite • Compost (to build healthier soil, conserve water and improve plant growth) • Pulverised/granulated lime (to increase the soil pH if needed)
Environment	• Although most herbs prefer direct sunlight (at least 6 hours per day), some prefer partial shade. • In order to grow herbs indoors, place fluorescent/LED light and position the lights close to the lights, adjusting the duration depending on the herb requirements. • Herbs typically thrive between 15°C to 24°C. • Some herbs are sensitive to frost and may need protection during colder months. • Herbs generally prefer well-draining soil (avoid water-logging). A mix of potting soil and perlite/sand can improve drainage. • If the pH drops below 5.0, pulverised/granulated lime could be added to increase soil pH. • Water herbs when the top part of the soil feels dry to touch, avoid over watering. • Moderate humidity level between 40-60%. (i.e. herbs originating from Mediterranean regions such as rosemary and thyme, often prefer low humidity whereas herbs from tropical regions such as, basil and mint may tolerate higher humidity. • Ensure good air circulation to prevent fungal diseases. especially in high humid environments. • For indoor growing humidifiers or placing a water tray next to the herbs can help increase humidity in drier seasons. • Ensure proper spacing between each herb to avoid overcrowding. Generally, small herbs need 15-30 cm while larger ones may require 30-60 cm or more. • Provide 15-30 cm of soil depth for roots to grow undisturbed.
Containment and safety.	Use appropriate protective equipment, including laboratory coats, safety goggles, and protective gloves. Before using chemicals, familiarise yourself with the MSDS sheets.
Disposal	• Composting • If additives are used and mixed with the moss and lichens, then the materials should be disposed according to the instructions and safety precautions
Extra Notes!	• Consider the growth habits of each herb. Some herbs such as mint can spread vigorously, planting these herbs in separate pots or containers can help control their growth and provide a healthier environment. • Some herbs could benefit from companion planting (where certain combinations promote growth and repel pests).

MOSS and LICHENS

Organism

Irish moss or Pearlwort (Sagina Subulata), Shiny Sexy Moss (Entodon Seductrix), Tufted Thread Moss (Bryum Caespiticium), Pincushion Moss (Leucobryum Glaucum)

Projects

Biophotovoltaics
Air Quality panels
Grow couture

Images

©Advanced Architecture Group, aeroSQAIR

Equipment/Tools

- Tray (for placing the substrates and organisms) and cover for the tray (to maintain the humidity levels)
- Spray bottle
- Shade cloth/partial shade area
- Sensors (for measuring temperature and humidity levels)
- Blender
- UV Grow light
- Arduino Board and components

Materials

-Moss spores/ moss clumps
  - Substrates: Peat moss, coconut coir or a mix of these with perlite or sand
  - Fertilisers: Yogurt, yeast, buttermilk, calcium carbonate

-Lichen fragments
  - Substrates: rocks, wood or other surfaces
  - Water Sources (for misting): Distilled or rain water

Environment

- Many moss and lichen species thrive at temperatures between 15°C and 25°C (specific temperature depends on the each species)
- Mosses and lichens often prefer high humidity levels, ranging from 40% to 80% (specific humidity conditions depends on the each species)
- While mosses prefer shaded areas, lichens prefer indirect light conditions.
- There are no species of moss that are harmful to humans; however, some lichen species are so it would be important to check before acquiring certain species.

Containment and safety.

The described moss and lichens are natural and non-harmful material that is safe to work with. There is no special safety equipment or regulated environment required. Use appropriate protective equipment, including laboratory coats, safety goggles, and protective gloves.
Before using chemicals, familiarise yourself with the MSDS sheets.

Disposal	• Composting • If additives are used and mixed with the moss and lichens, then the materials should be disposed according to the instructions and safety precautions
Extra Notes!	• It is important to keep the each substrate consistently moist but not waterlogged, a spray bottle can be used to mist regularly • Even though mosses and lichens requires humidity to grow, the cover of the tray should be removed occasionally for fresh air exchange • Lichens are sensitive to water quality, due to that, for misting tap water should be avoided. • Choose moss or lichen varieties in your region if possible.

ANIMALS

Organism

Invertebrates: bees, silkworms, mealworms
Animal products: Eggshells, seashells

Projects

Tiles
Structures
Materials

Images

©ovolo

©Worm Generation

Equipment/Tools

Sea/mussel/egg shells:
- Sterilizer
- Hand blender/grinder
- Spatula
- Boiler
- Sieve
- Drying oven/dehydrator
- Masks
- Disposable gloves
- Safety glasses

Bees, silkworms, mealworms:
- Sensors for monitoring temperature and humidity levels
- Enclosure for the species

Materials

Sea/mussel/egg shells
Binders: Sodium alginate, starch, pine resin, rosin, lignin, gelatine, agar agar
Silkworms
Mulberry leaves for nutrition
Mealworms
Substrates: Wheat bran, oats or a combination of grain-based materials
Bees
Nectar and pollen for nutrition
Water

Environment	Sea/mussel/egg shells • Room temperature • Egg shells are sensitive to moisture, 40-60% relative humidity levels should be aimed • Air circulation and proper ventilation should be aimed to avoid dust particles buildup Silkworms • The optimal temperature for silkworms are ranging from 25°C to 30°C • They prefer high humidity conditions, relative humidity from 75% to 85%. • Silkworms are sensitive to light and they should be kept under natural light cycles, simulating day and night. • The environment they are in should be cleaned regularly. • Enough space for moving around and feeding silkworms should be provided Bees • The optimal temperature range for honey bee activities are 10°C to 30°C. • Sunlight should be provided to ensure the bees can navigate themselves and regulate hive temperatures • Good ventilation should be provided to avoid moisture buildup • Enough space for colony population and activities should be ensured • Properly arranged and adequately spaced frames should be provided Mealworms • The optimal temperature for mealworms is from 25°C to 28°C. • Mealworms prefer low light levels, diffused or indirect light can be incorporated • The substrate should have consistent moisture level avoiding excessive wetness and humidity levels should be kept at 70%-80% • Good ventilation should be provided to avoid moisture buildup • Enough space for moving and burrowing should be ensured
Containment and safety.	These animal species have been selected as examples, based on successful biodesign projects. Remember it is always important to check the specific species requirements. This is especially important here before working with living invertebrates such as bees, worms and spiders.
Disposal	• Composting/ natural decomposition • If additives are used, then the materials should be disposed according to the instructions and safety precautions
Extra Notes!	The environment for the mealworms should be cleaned regularly to remove waste, exuviae (shedded exoskeletons) and any contaminated substrate.

What Next? A Shared Call for Action

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Interdisciplinary approaches are crucial to the future of education, research, and collaborative innovation, especially in the face of urgent environmental concerns. However, conceptualising, let alone mainstreaming bioFABLABs is not a simple undertaking, presenting us with inherent tensions that require careful balancing. Notably in bioFABLABs, it is crucial to uphold laboratory safety standards, while encouraging playful experimentation to nurture creative and exploratory mindsets. As discussed in this document, working with biological materials demands an understanding of their handling protocols, potential risks, and measures to mitigate harm. Therefore, bioFabLab's infrastructure, methods and guidance must be designed to effectively implement safety considerations, while simultaneously allowing a degree of freedom for students to test innovative ideas. In this sense, the notion of open-access transcends beyond mere democratisation of space and equipment - it is also strongly linked to the access to knowledge and resources. This entails implementing guidance structures to accommodate participants of diverse skill-sets, from novices to advanced users, coupled with the efforts to lower barriers to access - physical, financial, social, and mental - through readily available support systems.

In navigating these tensions, it is crucial to recognise that playfulness and safety are not mutually exclusive; rather, bioFABLAB's unique identity emerges from the very coexistence of these elements, creating a new kind of space for cultivating both systemic and affective competences. For instance, the students learn about other biological lives through altering and nurturing the habitats in which the organisms grow (Camere and Karana, 2018). While developing biological knowledge, the students are simultaneously encouraged to be creative with the ways in which they experiment - such as building their own DIY incubators or testing alternative feedstocks from local waste streams. We believe that providing students with both the mental and physical space for the "messy" work (as opposed to tightly-controlled and contained environments), equips them with the skills to navigate real-world uncertainties, unfamiliarities, and distributed agencies, as well as fostering opportunities to learn from failures, and to push boundaries beyond traditional constraints. Such an approach encourages creativity, curiosity, and exploration whilst instilling a deep sense of responsibility towards other lives.

Our research has shown that there are already best practices from existing (bio)fab labs and the field of biology education, which can serve as a foundational base towards mainstreaming bioFABLAB. At the moment, the landscape of these initiatives are broad - from home kitchen biolabs and grassroots community initiatives, to entrepreneurial labs and research institutions. We see contextual differences as strengths rather than the hindrance for mainstreaming, and would like to underscore that the envisioned bioFABLAB models are neither one-size-fits-all nor static. The uniqueness that arises from geo-cultural placeness informs respective objectives, necessities, or values, demanding that our mainstreaming effort is not one of uncontested universalisation, but of a continuous, ever-changing endeavour. Through CoCoon, we hope to create a fertile ground that would serve as an inspiration to many, and which would be nurtured and grown collaboratively with cross-disciplinary and cross-cultural participants.

Above all, we hope that this document becomes a conversation starter - an invitation to professionals, innovators, researchers, educators, students, and aspiring citizens to join the dialogue in this collaborative journey.

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