CO-CREATING GREENER FUTURES:

DEVELOPING AND TRANSFERRING INNOVATIVE BIO-DESIGN MODULES FOR EDUCATION TO ACCELERATE THE GREEN TRANSITION.

Deliverable | D 2.1

POLICIES REVIEW - BARRIERS AND OPPORTUNITIES FOR MAINSTREAMING BIO- DESIGN EDUCATION AND PRACTICES.

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Leading partner | COFAC

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Short Summary

Literature review, design policies benchmark, and state of the art about innovative biodesign policies pathways. A benchmark of existing bio-design concepts is performed in this report with the aim of building the Cocoon terminology framework. The included information mapping will show the evaluation of application of concepts to the field of design and to the following Cocoon scopes: design with living system, design with biomaterials, design with circular system, design with biomimicry.

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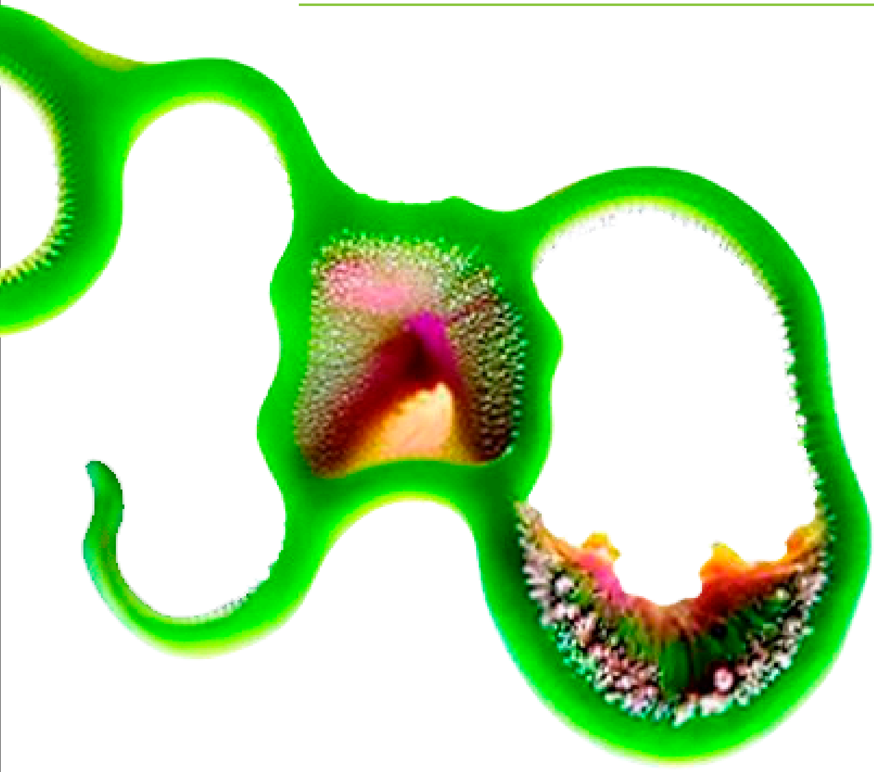


Introduction

CoCoon is a large-scale Erasmus project aimed at expediting the transfer and co-creation of knowledge within the domain of Biodesign and Biofabrication. This endeavor unites a multidisciplinary team of experts hailing from seven institutions across five European Union countries (COFAC and BIOPOLIS from Portugal; AALTO from Finland; IAAC from Spain, and FB from Iceland). The collective commitment of these institutions lies in sharing experiences and generating new knowledge to foster a sustainable and environmentally friendly future.

This report has intended to map, cluster, analyse and synthesise information, to inform the work package 5 - biodesign policies, and bio-definitions, in building Cocoon's educational and VET training programmes and living labs.
Regarding biodesign policies, the mapping focus on design policies and then searching the gaps to be filled by a policy suitable for biodesign.
The bio-terms follow a chronological mapping of the evolution of definitions and the field itself, allowing to identify their suitability and significance for the development of project Cocoon.

(BIO)Design Policies?

Biodesign Policies as a walk in the researcher's mind.

by Gabriel Patrocinio

*"Learn from nature: that is where our future lies"*_ Leonardo Da Vinci

To address the issue of Biodesign Policies, in the sense adopted by the Cocoon Project, it is necessary to make an introduction on Design and Nature, on the study of the Policy and on the framework of Design Policies to finally arrive at Biodesign Policies. This will allow us to better understand what we need to achieve within the framework of the project.

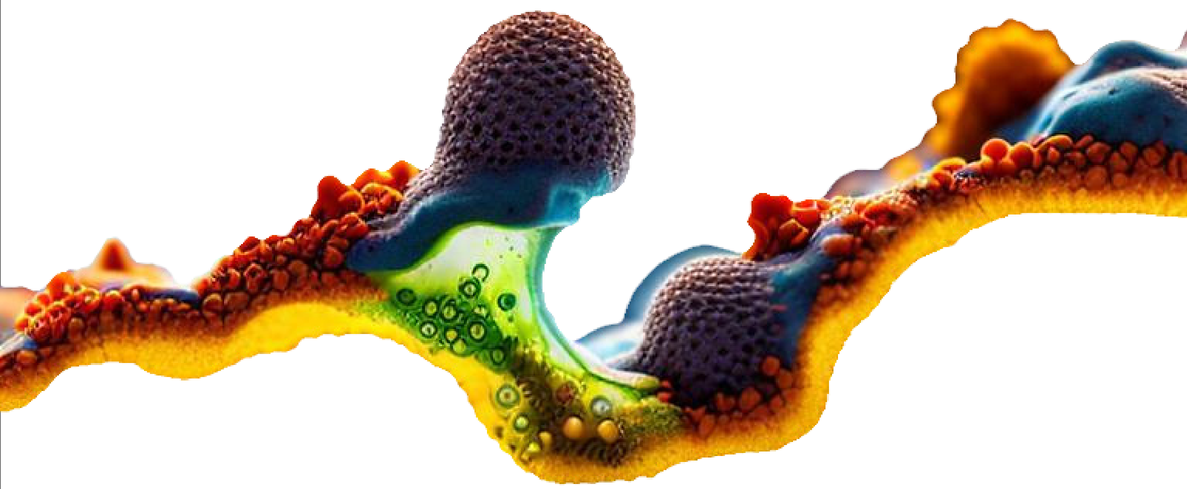
DESIGN AND NATURE

Forms and structures from nature have always served as inspiration for art and design for thousands of years. Vitruvius, Roman architect from the first century BC, in his treatise *De Architectura*, said that "natural phenomena serve as models to shape technological works", and that the observation of "the patterns of natura (...) triggers humans to invent and develop all kinds of technology" (Roby, 2013). In the Renaissance, Leonardo Da Vinci developed studies that have been sparking human imagination ever since.

Not disregarding all predecessors, direct inspiration from nature was a concern brought back to design education in the 1970s, by authors such as Victor Papanek, Buckminster Fuller, Bruno Munari and Gui Bonsiepe.

The mimicking of nature has been called different names, sometimes with slightly different meanings, since the second half of last century - bionics, biomimetics, biomimicry, biodesign.

Bionics was a trend discussion in the field of design during the 1970s-1980s, especially with the dissemination of the ideas of Papanek. In line with this trend, back in 1987 the Brazilian Industrial Design Lab (LBDI) located in Florianopolis, held a section of Biodesign Research, offering, in 1986 and 1988, workshops on Bionics applied to Design (Barroso Neto, 1998). Biodesign seems to be a natural successor of the idea of bionics and biomimetics, but more recently has been frequently associated with bioengineering, and to biomedical and pharmaceutical research.



BIONICS: “science of constructing artificial systems that have some of the characteristics of living systems” (Britannica.com); “the study of how humans and animals perform certain tasks and solve certain problems, and of the application of the findings to the design of electronic devices and mechanical parts” (Dictionary.com); “the use of biological prototypes for the design of man-made synthetic systems” (Papanek, 1971).

BIOMIMETICS: “the study and development of synthetic systems that mimic the formation, function, or structure of biologically produced substances and materials and biological mechanisms and processes” (Dictionary.com); “the field of science and engineering that seeks to understand and to use nature as a model for copying, adapting, and inspiring concepts and designs” (Bar-Cohen, 2012).

BIOMIMICRY: “the mimicking of life using imitation biological systems” (Dictionary.com)

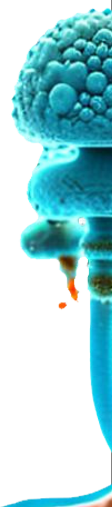
BIODESIGN: “Tendance du design s’inspirant de formes naturelles, végétales ou animales” (Design trend inspired by natural, vegetal or animal forms - Larousse.fr)

BIOLOGICALLY INSPIRED DESIGN or BIO-INSPIRED DESIGN (BID): “technique for complex problem solving using analogical design, where novel designs in one domain (engineering, architecture, etc.) are created by drawing upon solutions and patterns in the different domain of, for example, biology” (Yen et al., 2012, p.345)

In this century, the University of Stanford is considered to be the pioneer in setting up a Biodesign laboratory in the year 2000 - however dedicated to biomedical and bioengineering research, while design schools have applied the term to the research in biomimetics and biomaterials. Since then, the term Biodesign has been torn between these two (almost) different perspectives.

POLICY

Christopher Freeman, from the Science Policy Research Unit, Sussex University, has freshened up the ideas of the German American economist from the 19th Century, Georg Friedrich List. Freeman highlights that List advocated for “broad range of policies designed to accelerate, or to make possible, industrialization and economic growth”, “the importance of new investment embodying the latest technology” and “the importance of learning by doing” in industry. This may seem obvious today, nearly two hundred years after it was written by List, but they are all arguments for a Biodesign policy – and the idea of “learning by doing” lays the foundations for Cocoon.



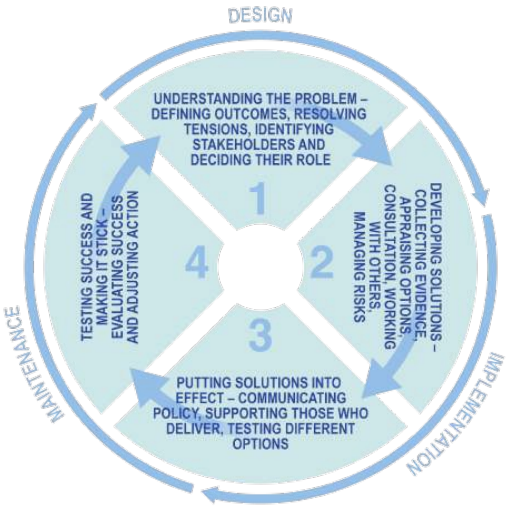
Freeman continues arguing for the need to have adequate policies to help connecting Academy and industries:

> “What has perhaps not been sufficiently recognized is the extent to which policies for science and technology are intertwined with policies for trade and industry. The ‘coupling mechanisms’ between the education system, scientific institutions, R&D facilities, production and markets have been an important aspect of the institutional changes introduced in the successful ‘overtaking’ countries” (Freeman, 2004).

Authors in the field of public policies suggest that some policies could be tested in small scale and controlled situations (Weiss & Birckmayer, 2006; Crawford, 2006). According to Crawford (2006) small scale modelling "help decision makers and observers make 'rational' judgments about complex and technical public policy questions."

Cocoon aims to be itself a small-scale model and to spark a debate about the need for specific policies towards biodesign.

Figure 01: Model for Policy-Making (Patrocinio, 2013, p. 26; after Bourn, 2001)



According to the Model for Policy Making of Bourn (2001) (Figure 01), there are three general phases – Design, Implementation, and Maintenance – and four action stages, as depicted here:

DESIGN
[1] Understanding the problem - defining outcomes, resolving tensions, identifying stakeholders and deciding their role.

DESIGN/IMPLEMENTATION
[2] Developing solutions - collecting evidence, appraising options, consultation, working with others, managing risks.

IMPLEMENTATION
[3] Putting solutions into effect – communicating policy, supporting those who deliver, testing different options.

MAINTENANCE
[4] Testing success and making it stick - evaluating success and adjusting action.

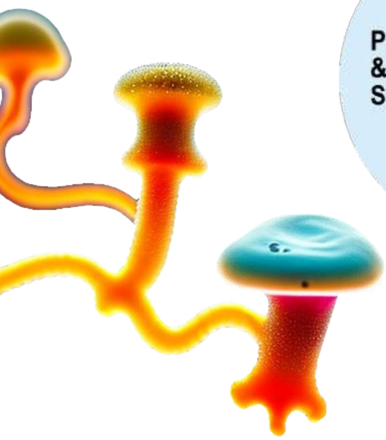
In line with the scope defined for Cocoon, the core of the proposal for a Biodesign Policy should focus on stages 1 and 2, although it may be considered, in the future, to address stages 3 and 4 in a subsequent project, together with the decision instances.

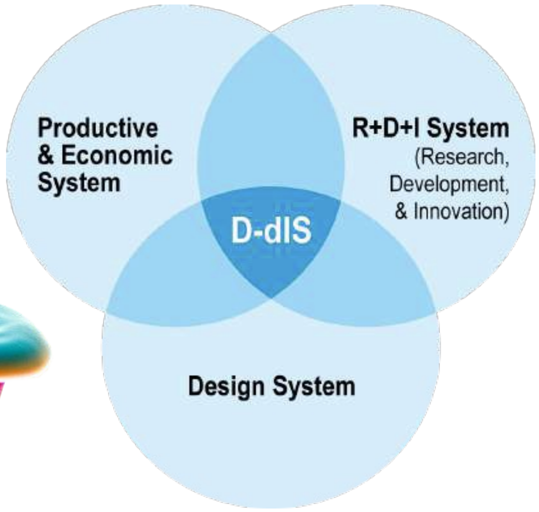
DESIGN POLICIES

Design Policies are a "set of principles established by a government to apply Design as a tool to leverage social, economic, industrial, and regional development." (Patrocinio, 2013, p. 19). Within the framework of Design Policies – but also of S&T and Innovation policies – there are several slots where to accommodate biodesign policies.

Borja de Mozota (2003) explains that Design has today a paramount role in innovation and the process of transferring new technologies to the market. Mollenhauer & Korvenmaa (2007) developed the model on Figure 02 to determine a Design-driven Innovation System (D-dIS):

FIGURE 02: Design-driven Innovation System (D-dIS) model
(Patrocinio, 2013, p. 69; after Mollenhauer & Korvenmaa, 2007)

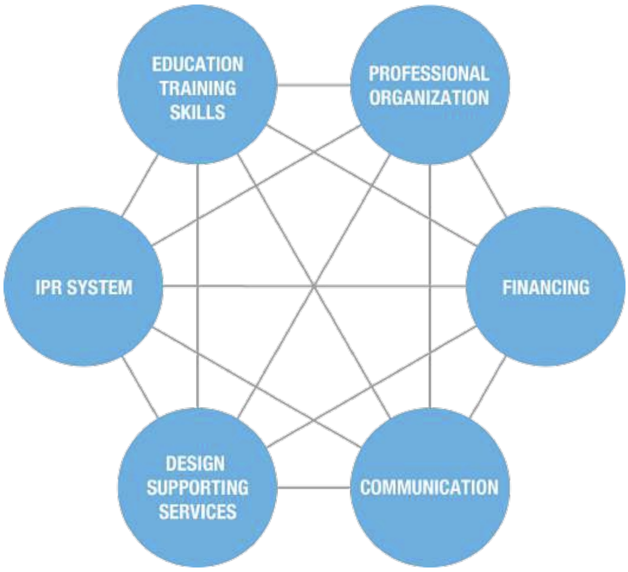




We can position Biodesign policies as a part of the Design-driven Innovation System (referred by Mollenhauer & Korvenmaa, 2007), as they intersect the RD&I System, of the Design System, and also of the Productive & Economic System.

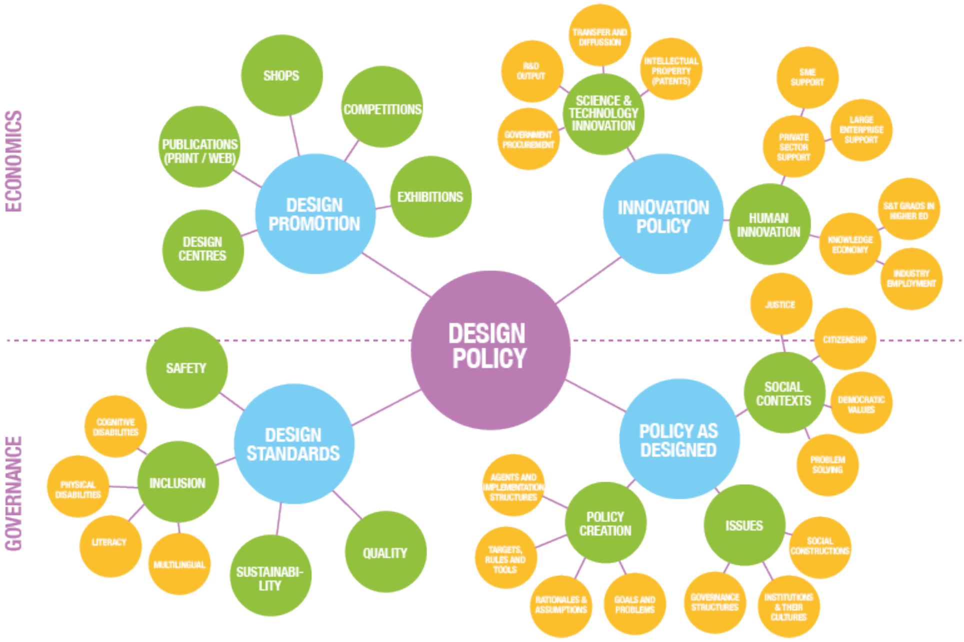
Biodesign policies operate under the same conceptual framework of design policies shown in Figure 03. It needs to interface and interact with the educational system, be supported by the IPR system, be offered funding and support, be properly communicated and promoted with, within, and by professional organizations.

FIGURE 03: Basic infrastructure for the operation of design policies
(Patrocinio, 2013, p.157-158)



In the Design policy landscape model developed by Elizabeth Tunstall, while advising the Obama administration in 2007 we can foresee several indicators for situating a Biodesign policy, starting from the Governance right quadrant (Policy as designed - where the very biodesign policies are engendered) and going anticlockwise through Innovation policies, Design promotion and generating (new) Design standards (or the objective aspects of the biodesign policies).

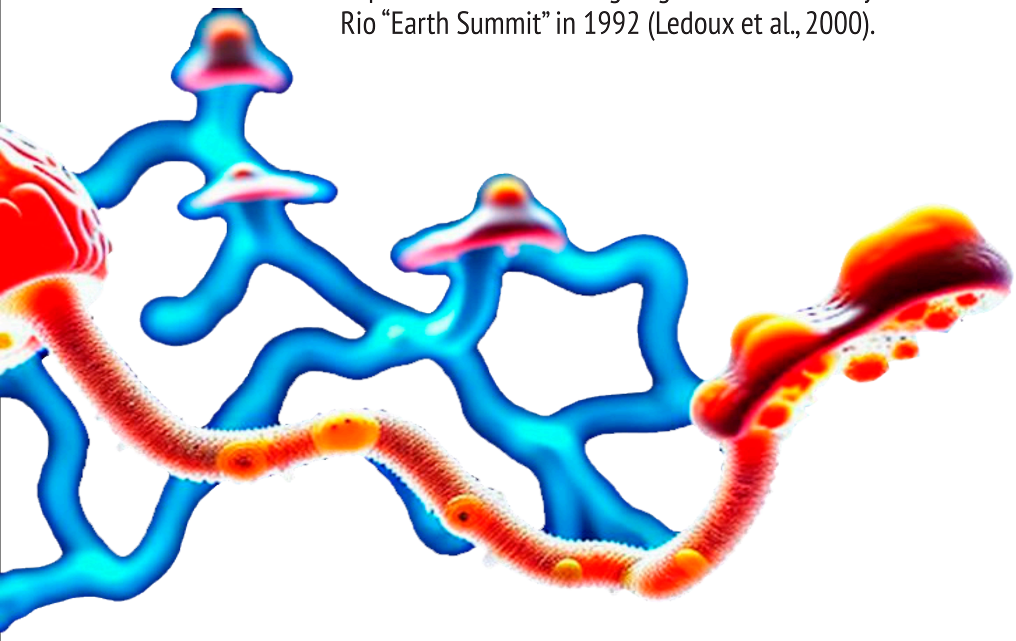
FIGURE 04: Design policy landscape (Tunstall, 2007, p. 3)



BIODESIGN POLICIES

What do we mean when we talk about Biodesign Policies in the context of this project?

From a recent historical perspective, we may understand the importance given to bionics, biomimetics and biodesign either by authors like Bonsiepe or reports prepared and published by the EU. However, there are not identifiable biodesign policies that may provide guidance to bio-inspired research and development. The closest policies that may be found relates to biodiversity policies, implemented after the signing of the Biodiversity Convention at the Rio "Earth Summit" in 1992 (Ledoux et al., 2000).



Setting up a framework for national design policies, Gui Bonsiepe drew a matrix of the domains of design and stages of development, including the studies on bionic design in the fourth of the five phases of the development of design competencies from a national perspective. According to this matrix, on the highest level design integrates scientific research multidisciplinary teams (Bonsiepe, 1991, pp.255).

Design for Growth and Prosperity (Thomson and Koskinen, 2012) is the Report and Recommendations of the European Design Leadership Board, published by the European Commission. From this report we may identify several recommendations that could be related to Cocoon and with the establishment of biodesign-related policies to support the development of the field. In fact, while the programme that enables the existence of Cocoon is itself a consequence of the policies endorsed by that report, it also supports the need for specific policies towards the development of biodesign research and facilities. The proposed Strategic Actions and Recommendations (pages 8-11 of the cited document), so relevant to Cocoon, are summarised in the Annex_1.

Biomimetics is proposed as a strategy for a new European policy on plastics in a report prepared by Cripa et al. (2019). The name of the report says it all: “A circular economy for plastics – Insights from research and innovation to inform policy and funding decisions.”

Such are the objectives of the Cocoon project regarding biodesign policies - to offer a contribution regarding safety, protocols, best practices, communication, support and funding, among others, to inform EU policy and funding decisions.

SAFETY: When it comes to biomaterials, there are many concerns that must be taken into account, such as the dangers to users and the environment, which must be known from the moment a new material is chosen to be used. As it is unreasonable to make a comprehensive catalogue of all natural materials and their hazards, there must be policies for how a new or unknown material should be introduced – or not. From the use of individual safety equipment to the avoidance or caution with those that may pose a greater degree of risk.

PROTOCOLS: What are the protocols to be followed - safety, standard procedures, etc; what has been previously established and what new protocols can facilitate the development of new research laboratories - and even maker laboratories with an emphasis on biomaterials. Protocols also cover standards, definitions, vocabulary, etc.

BEST PRACTICES: What are the references, best practices, processes, minimum or desirable suitable equipment, safety measures and useful tips for starting and keeping a biodesign laboratory.

COMMUNICATION: How communication can be used to spark interest; how to communicate results effectively; reporting, self-advertising, media, publishing; how to reach the market with the help of communication.

SUPPORT: What kind of support is needed at each stage of a biodesign laboratory; what support networks are available.

FUNDING: Where to get funding; what kind of calls can support biodesign lab projects; what to consider when making an application.

CONCLUSION

Currently, most policies that address the issue of biodesign are related to healthcare and health technologies, and to pharmaceutical and biomedical research. According to Lebdioui (2022), "biomimicry/biomimetics remains largely overlooked in economics, public policy, and development studies." The authors further state that the absence of specific policies to bio-inspired innovation "hinder the expansion and commercialization of biomimicry-based R&D."

Thus, one of the goals of Cocoon Project is to provide insights to inform specific policies for the field of biodesign. The first action regarding this issue is a workshop to discuss biodesign policies to be held in September 2023 at Aalto University, with the goal to establish directives to inform these policies.

REFERENCES:

Bar-Cohen, Y. (2012). Biomimetics: nature-based innovation. Boca Raton: CRC press.

Barroso Neto, E. (1998), Laboratório Brasileiro de Design - Uma história que não terminou 1984-1997 (Brazilian Design Laboratory - An history that has not ended 1984-1997), ABIPTI, Fortaleza. Available at http://www.scribd.com/doc/3734480/lbdi (accessed 26 June 2023)

Bonsiepe, G. (1991), Developing Countries: Awareness of Design and the Peripheral Condition, in: Castelnuovo, E. (ed.), History of Industrial Design - 1919-1990 - The Dominion of Design, Electa, Milan.

Borja de Mozota, B. (2003), Design management: using design to build brand value and corporate innovation, Allworth Press, New York.

Bourn, J. (2001), Modern Policy-Making: Ensuring Policies Deliver Value for Money, National Audit Office, London. Available at https://www.nao.org.uk/reports/modern-policy-making-ensuring-policies-deliver-value-for-money/ (assessed 26 June 2023).

Crawford, N. C. (2006), Policy modelling, In: Moran, M., Rein, M., and Goodin, R. E. (eds.), The Oxford handbook of public policy, Oxford University Press, p. 771-804.

Crippa, M., De Wilde, B., Koopmans, R., Leyssens, J., Muncke, J., Ritschkoff A-C., Van Doorsselaer, K., Velis, C. & Wagner, M. (2019). A circular economy for plastics – Insights from research and innovation to inform policy and funding decisions (M. De Smet & M. Linder, Eds.). European Commission, Brussels, Belgium. (doi:10.2777/269031)

Freeman, C. (2004), Technological infrastructure and international competitiveness, Industrial and Corporate Change, Vol.13, No.3, p.541–569.

Ledoux, L., Crooks, S., Jordan, A., & Turner, R. K. (2000). Implementing EU biodiversity policy: UK experiences. Land use policy, 17(4), 257-268.
Lebdioui, A. (2022). Nature-inspired innovation policy: Biomimicry as a pathway to leverage biodiversity for economic development. Ecological Economics, 202, 107585.

List, F. (1845), The National System of Political Economy, (English translation by Lloyd, S. S), Longman, London (1904).
Love,T. (2007), National design infrastructures: the key to design-driven socioeconomic outcomes and innovative knowledge economies, in: proceedings of the International Association of Societies of Design Research IASDR'07, The Hong Kong Polytechnic University, Hong Kong, available at http://www.sd.polyu.edu.hk/iasdr/proceeding/html/sch_day4.htm (accessed 26 June 2023)

Mollenhauer,K. & Korvenmaa P. (2007), Designing the Designer: the Responsibilities of Education in the National / Regional Systems of Design, in proceedings of the International Conference on Engineering and Product Design Education, Northumbria University, Newcastle Upon Tyne, UK. Available at http://www.designsociety.org/publication/27299/ds_43_proceedings_of_epde_2007_the_9th_international_conference_on_engineering_and_product_design_education_university_of_northumbria_newcastle_uk_13-14_09_2007at
(accessed 26 June 2023).

Papanek, V. (1972), Design for the real world, Thames & Hudson, London.

Patrocinio, G. (2013). The impact of European design policies and their implications on the development of a framework to support future Brazilian design policies. (Doctoral Dissertation, Cranfield University, UK). Available from http://designpolicies.blogspot.com/2014/10/design-policies-thesis.html (Accessed 26 June 2023).

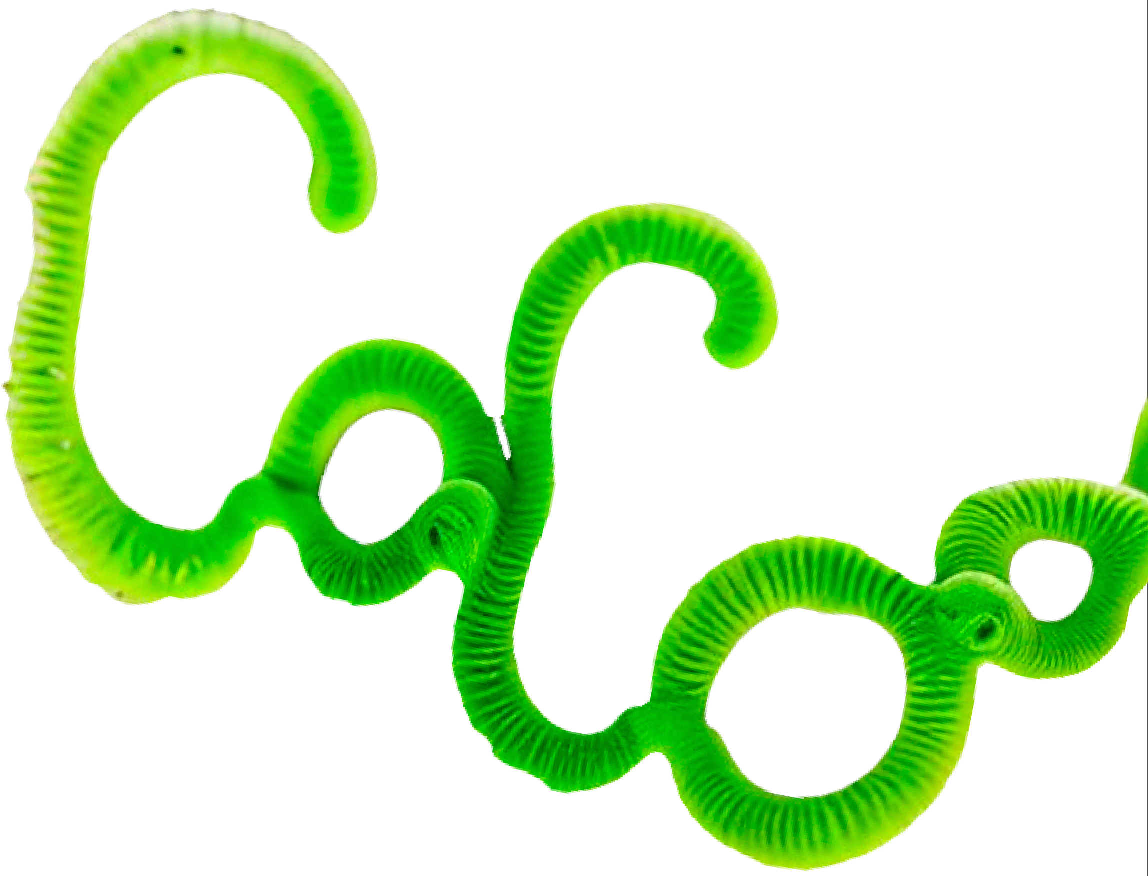
Roby, C. (2013). Natura machinata: artifacts and nature as reciprocal models in Vitruvius. Apeiron, 46(4), 419-445. https://doi.org/10.1515/apeiron-2012-0041

Thomson, M.; Koskinen,T. (2012), Design for Growth and Prosperity - Report and Recommendations of the European Design Leadership Board, DG Enterprise and Industry; European Commission. Available at https://op.europa.eu/en/publication-detail/-/publication/a207fc64-d4ef-4923-a8d1-4878d4d04520 (accessed 26 June 2023).

Tunstall, E. (2007), Mapping the Design Policy Landscape, in SEE Design Bulletin, Issue 5, p.3-6, PDR National Centre for Product Design & Development Research, Cardiff, UK. Available at https://web.archive.org/web/20141016222514/http://www.seeplatform.eu/publications (accessed 26 June 2023).

Weiss, C.H. and Birckmayer, J. (2006), Social experimentation for public policy, In: Moran,M., Rein,M., and Goodin,R.E. (eds.), The Oxford handbook of public policy, Oxford University Press, p. 806-830.

Yen, J.; Weissburg, M.J.; Helms, M.; Goel, A,K. (2012). Biologically Inspired Design: A Tool for Interdisciplinary Education. In: Bar-Cohen, Y. Biomimetics: nature-based innovation. Boca Raton: CRC press.



(BIO)terms

Biodesign and bioterms definitions as a walk in the researcher's mind.

by Carla Paoliello

In order to comprehensively examine the primary definitions of Biodesign and related terms under the perspective embraced by the Cocoon Project, a methodical literature review was undertaken. It facilitated the exploration of terms such as Biodesign, Biofabrication, Biomimicry, Bio-circular, and Biomimetics, intending to establish a sequential timeline. This chronological framework enabled a more profound comprehension of the project's objectives and the desired outcomes pursued.

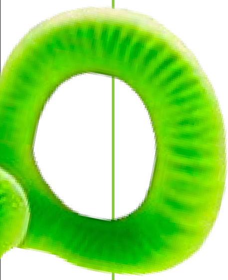
Keywords: Biodesign, Biofabrication, Biomimicry, Bio-circular.

INTRODUCTION

CoCoon is a large-scale Erasmus project aimed at expediting the transfer and co-creation of knowledge within the domain of Biodesign and Biofabrication. This endeavor unites a multidisciplinary team of experts hailing from seven institutions across five European Union countries (COFAC and BIOPOLIS from Portugal; AALTO from Finland; IAAC from Spain, and FB from Iceland). The collective commitment of these institutions lies in sharing experiences and generating new knowledge to foster a sustainable and environmentally friendly future.

An early undertaking within this project involved mapping and delineating biology concepts that can be effectively applied to the design field. Despite the longstanding exploration of nature-inspired design and the familiarity of terms such as Bionics, Biomimetics, and Biomimicry among designers, a degree of incertitude surrounds the definition of Biodesign and other related bio-terms.

To bridge this knowledge gap, we conducted a systematic literature review, following the methodology outlined by Fink (1998). Our objective was to identify and evaluate relevant literature on this subject, thereby establishing a chronological timeline reflecting the key publications on each bio-term.



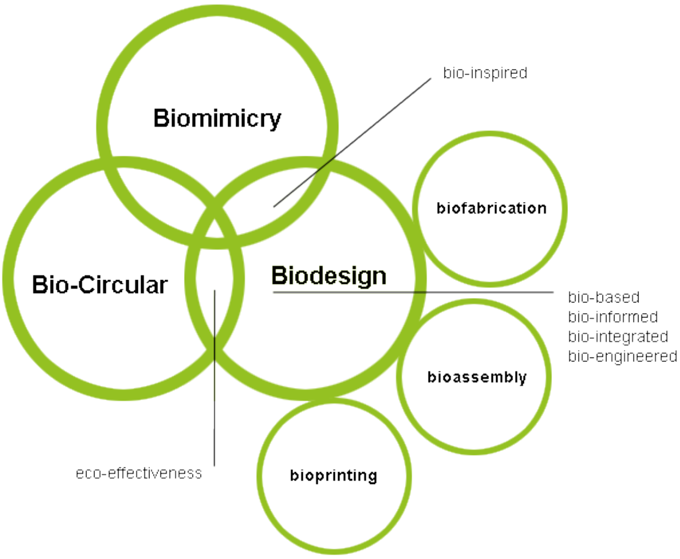
To commence our review, we formulated the primary research questions: How can Biodesign be defined? Which other bio-terms associated with Biodesign are crucial for comprehending this concept? Google Scholar and Research Gate were selected as our research sources. Initially, we employed the search term "biodesign," which yielded an overwhelming 44,200,000 results. Subsequently, we refined our search by utilizing "biodesign definition," resulting in 18,800,000 hits. To further narrow our focus, we excluded architectural, medical, and tissue (health technology field) application results, resulting in 4,300 publications. Introducing the term "biomaterial" further reduced the outcome to 211 papers. Lastly, we added "biofabrication" to our search parameters, yielding 42 relevant results. By carefully managing our criteria for inclusion and exclusion, we ensured a more targeted compilation of scholarly works.

The retained papers were then meticulously examined in their entirety. We scrutinized the literature, paying particular attention to bio-terms and their respective definitions while simultaneously pursuing additional references of significance. Our final analysis encompassed 85 articles, 33 books, 8 exhibitions, and 10 videos.

BIO-TERMS DEFINITIONS

As previously outlined, we sought to trace the historical development of the research topics to establish a comprehensive reference framework for Biodesign. Therefore, among the notable bio-terms we encountered alongside Biodesign were Biomimicry, Bio-circular, Biofabrication, Bioprinting, and Bioassembly (fig. 5).

FIGURE 05. Main bio-terms analyzed.



BIODESIGN

In 2012, William Myers popularized the term "Biodesign" as a novel and potentially unconventional approach to design. Biodesign draws inspiration from biological principles, and, unlike Biomimicry or Cradle to Cradle, it goes beyond mere imitation or sustainable practices. It actively incorporates living organisms into its design processes (Collet, 2013) or dead biomass that was once a living organism itself (Esat & Ahmed-Kristensen, 2018, p.1039), figure 6. It involves designing with, from, or for biology itself.

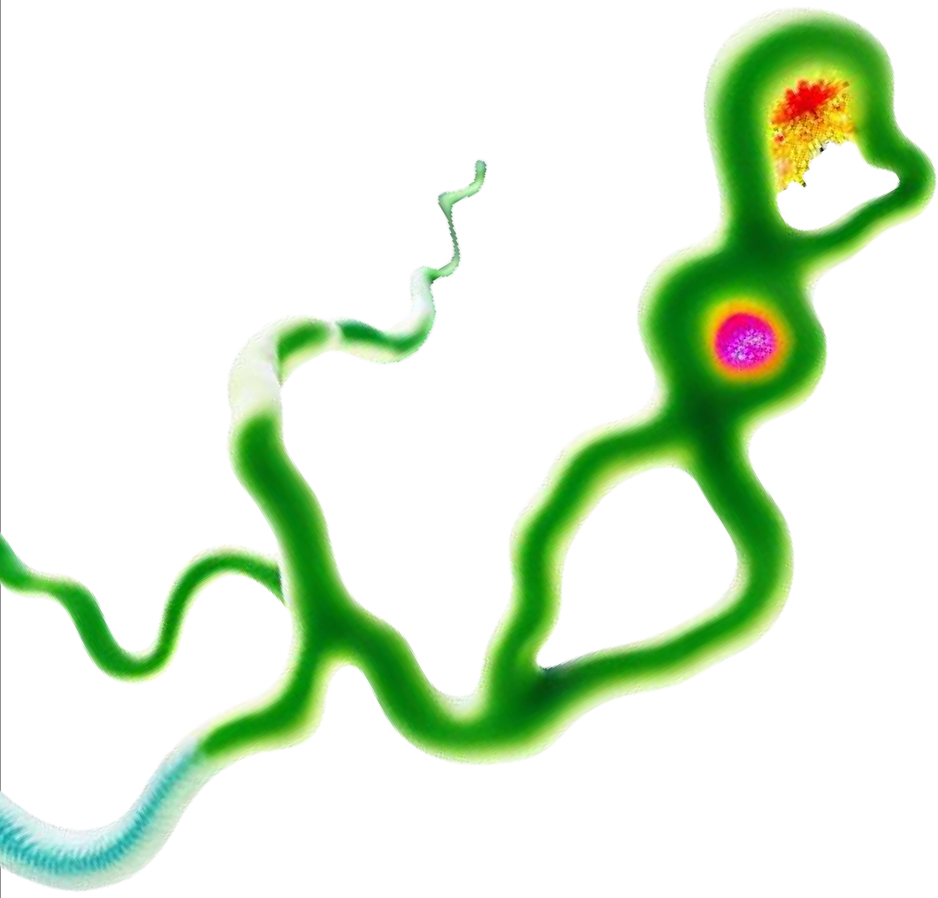
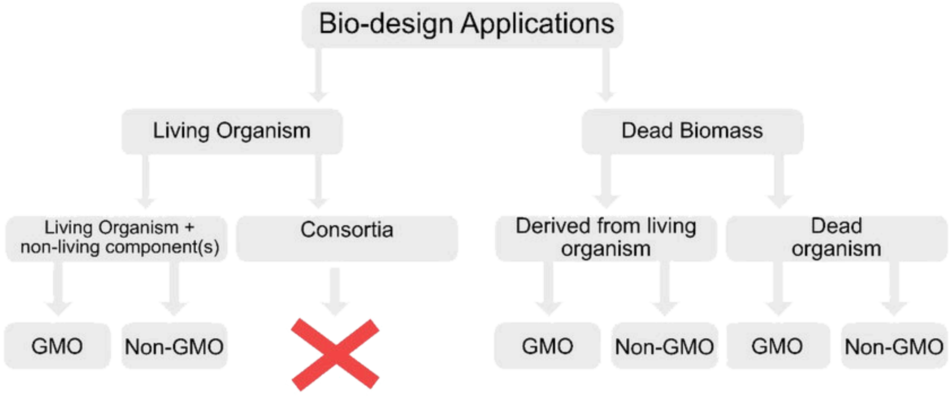
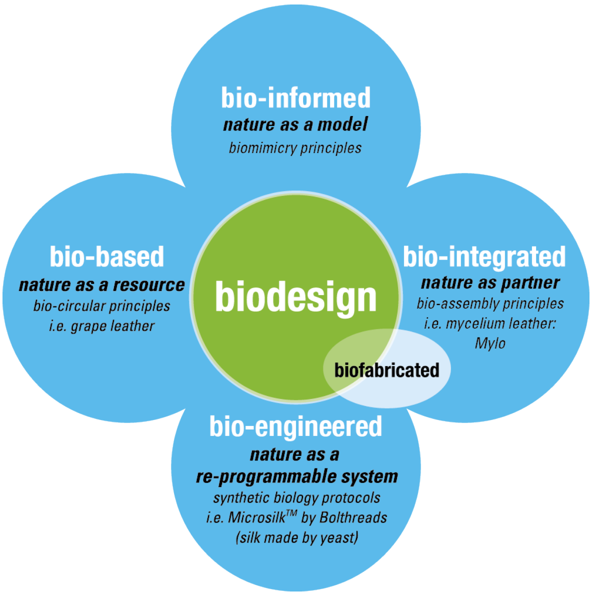


FIGURE 06. Classes and sub-classes of bio-design applications by Esat & Ahmed-Kristensen (2018).



The practice of Biodesign encompasses a variety of design strategies. These strategies include bio-based design, which utilizes nature as a resource; bio-informed design, which takes inspiration from nature as a model; bio-integrated design, which treats nature as a collaborative partner; and bio-engineered design, which involves programming and manipulating nature in a reconfigurable manner as in fig. 7 by Collet (2020).

FIGURE 07. A framework for designing with living systems by Collet (2020). https://ext.maat.pt/bulletin/biodesign

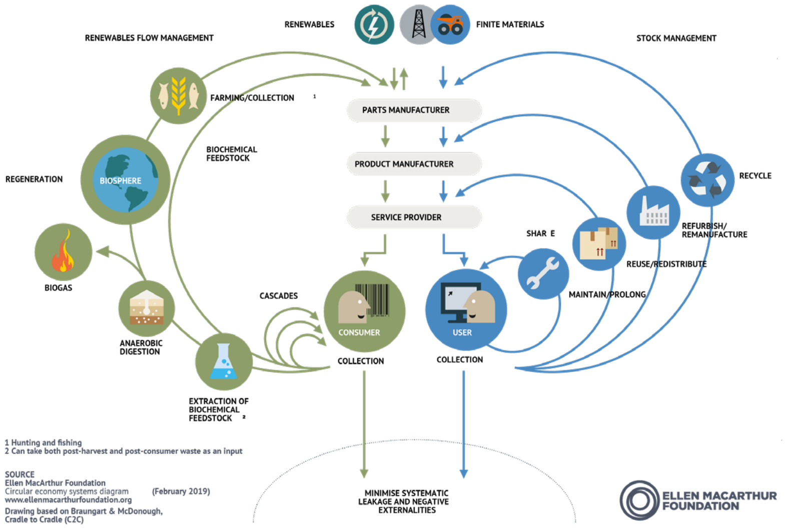


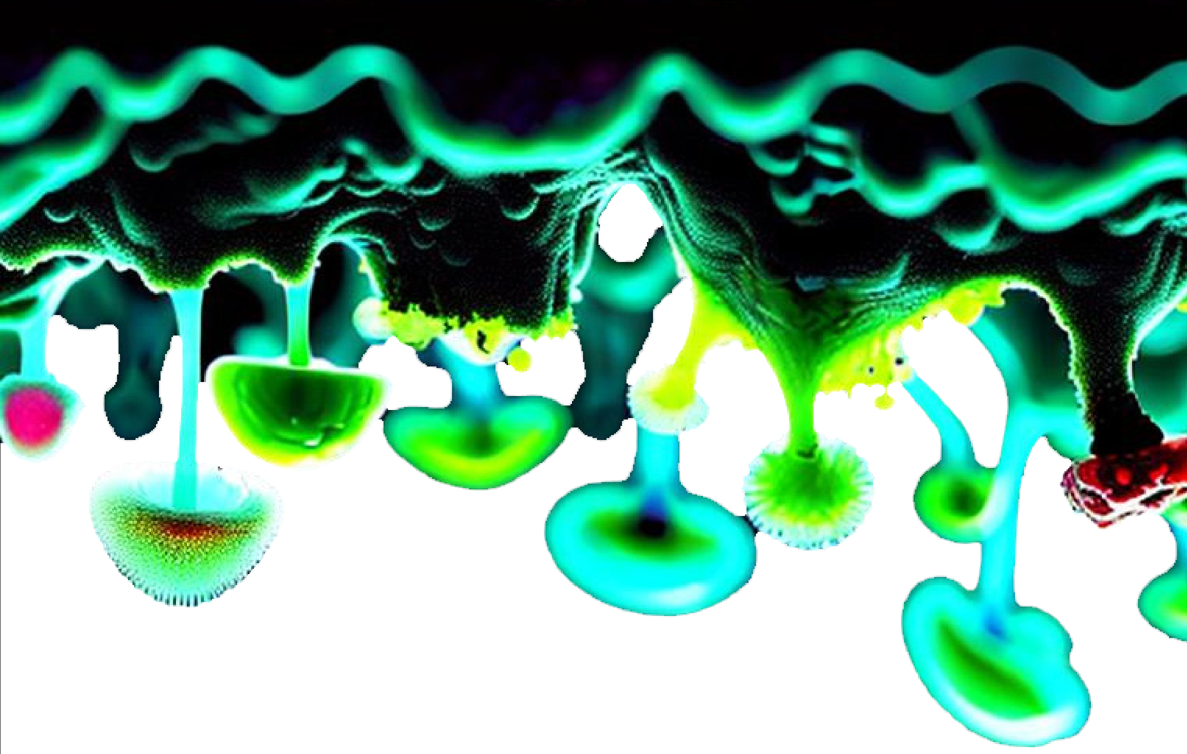
Furthermore, Biodesign integrates the fundamental principles that support life within biological systems into the design process. Doing so aims to foster a more comprehensive, sustainable, and regenerative future.

BIO-CIRCULAR (CRADLE-TO-CRADLE)

Braungart and McDonough (2002) are credited with pioneering the concept of "Cradle to Cradle," which is built upon two interconnected principles: "waste equals food" and "eco-effectiveness." Cradle to Cradle or Bio-circular encourages a shift beyond mere eco-efficiency and promotes adopting an "eco-effective" approach, urging individuals and organizations to embrace this mindset (fig. 8).

FIGURE 08. Cradle to Cradle design paradigm. https://c2cplatform.tw/en/c2c.php?Key=1



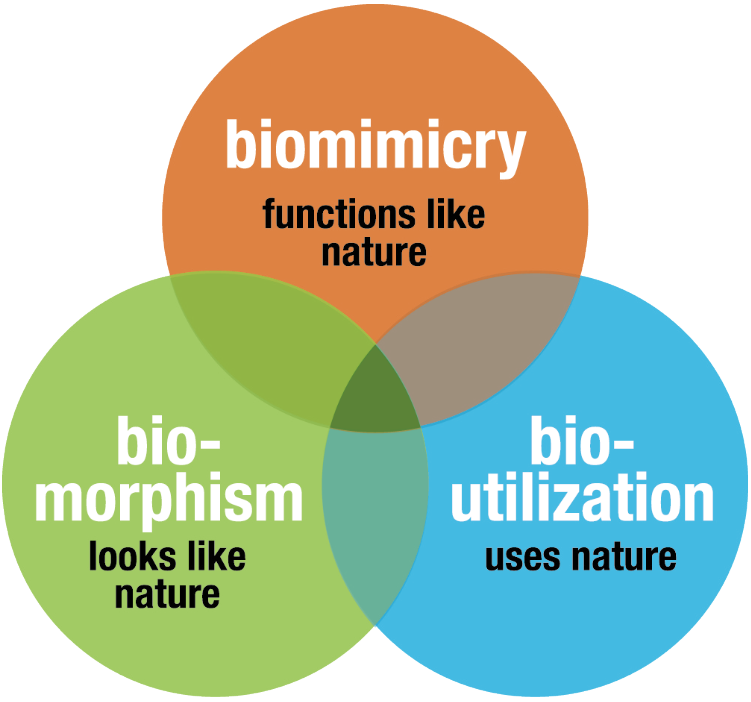


BIOMIMICRY

Biomimicry, Bio-inspired design, Bionics, or simply Nature-inspired design are all terms used interchangeably to refer to a philosophy and interdisciplinary design approach that draws inspiration from nature to address sustainable development challenges.

As Benyus (1997) described, this approach involves utilizing nature as a model, measure, and mentor. By studying and understanding the models and processes found in nature, designers can adapt and apply them to solve human problems. An ecological standard derived from nature is used to assess the suitability and effectiveness of innovations; meanwhile, using nature as a mentor emphasizes learning from it rather than exploiting it (fig. 9).

FIGURE 09. Biomimicry diagram by Benyus (1997). https://biomimicry.org/what-is-biomimicry/



BIOFABRICATION

The term "Biofabrication" was initially used to describe the biomineralization of pearls (Fritz et al., 1994), a type of biological fabrication that happens naturally. Introduced by Mironov et al. (2009) more recently to describe the synthesis process of living and non-living biological outputs using various raw materials, including living cells, molecules, extracellular matrices, and biomaterials.
Initially focused on biomedical applications, Biofabrication has expanded its scope to include developing sustainable materials for manufacturing purposes, and is more broadly defined as a 'fabrication of materials by living organisms' (Camere & Karana, 2018, p.570). It often requires a foundation in biology and draws inspiration from biological systems. It encompasses many physical, chemical, biological, and engineering processes.

BIOPRINTING

According to Mironov, Reis, and Derby (2004), Bioprinting is characterized as applying material transfer techniques to arrange and construct biologically significant materials. These materials include molecules, cells, tissues, and biodegradable biomaterials, intending to achieve specific biological functions.

BIOASSEMBLY

"Bioassembly" refers to constructing hierarchical structures with a predetermined 2D or 3D organization. This is achieved through the automated assembly of pre-formed fabrication units that contain cells. These fabrication units are generated through cell-driven self-organization or by preparing hybrid building blocks of cells and materials. Preparing such building blocks often involves using enabling technologies such as micro-fabricated molds or microfluidics.

BIO-TERMS TIMELINE

Those six terms were important to CoCoon, although we could find that the earliest concern about resource limits and our material production impact on the environment were traced back to Fuller's work (1969). While he did not pioneer environmental concerns, he was the individual who initially contextualized these concerns within the realm of design.

After that, there is the seminal book of Papanek (1970/72), 'Design for the Real World: Human Ecology and Social Change,' calling for more responsible design practice. Green design practice was the focus of Maldonado, T. (1971) in 'Design, Nature & Revolution: Toward a Critical Ecology'; Meadows, D. H. et al. wrote 'The Limits to Growth' in 1972; and Lee-Smith, D. & Gloster, M. (1975) explained an 'Eco-design project' in their homonymous book, and Lovelock, J. E. explained the Gaia's Theory in 1979.

Biophilia was explained by Wilson, E. O. (1984), Brundtland, G.H. (1987) reinforced the problems on Environment and Development at 'Our Common Future' and the relationship of Biology and Materials was the main topic of Alper, M. (1992). From then on, there was a significant amount of publications focused on lowering environmental impact through redesigning materials and products.

Additionally, other highlighted titles are: 'Biomimicry: Innovation Inspired by Nature' by Janine Benyus (1997); 'Strategic Design for Sustainability: Towards a New Mix of Products and Services' by Manzini, E. (1999); 'The Perception of the Environment: Essays on Livelihood, Dwelling and Skill' by Ingold, T. (2000); 'Cradle to Cradle: Remaking the Way we Make Things' by McDonough, W. & Braungart, M. (2002); 'Bio Design Products: Co-Design with Nature by Koivumen, H. (2005); 'Bioprinting: a beginning' by Mironov, V., Reis, N., & Derby, B. (2006); 'Design for Environmental Sustainability - Life Cycle Design of Products' by Vezzoli, C. A. (2008); 'Biofabrication: a 21st-century manufacturing paradigm' by Mironov, V. et al. (2009); 'Nature Inspired Design: strategies towards sustainability' by Karana, E., et al. (2010).

The list continues with: 'Biodesign: Nature, Science, Creativity' by Myers, W., 'How forests think: Toward an Anthropology Beyond the Human' by Kohn, E., both from 2012, and 'This is Alive' by Collet, C. (2013). From 2015, we recommend the ISO/TC266 'Biomimetics - Terminology, concepts and methodology' and the works 'DIY materials' by Rognoli, V. et al.; 'Material driven design (MDD): A method to design for material experiences' by Karana, E., et al. and 'Design at the intersection of technology and biology,' a TED Talk by Oxman, N.

In 2017, the focus changed to designing with the living, and the papers 'Growing materials for product design' by Camere, S. & Karana, E. and 'Designing with living organisms' by Moisy, A. & Pschetz, L. were essential readings because they understood the impact of fabricating materials from living organisms as an emerging design practice. Moreover, Esat, R. & Ahmed-Kristensen, S. (2018) classified some Biodesign applications. As they explained, "a new design paradigm, bio-design incorporates living organism and their processes as well as material derived from living organisms. It presented a new frontier in terms of design with nature as opposed to design by nature in the case of bio-inspired design" (p. 1031).

The latest articles are: Escobar, A. (2018). 'Designs for the Pluriverse: Radical Interdependence Autonomy and the Making of Worlds' by Escobar (2018); 'Living artefacts: Conceptualizing livingness as a material quality in everyday artefacts' by Karana, E., Barati, B., & Giaccardi, E. (2020); 'Ecologies of Repair: A Post-human Approach to Other-Than Human Natures' by Blanco-Wells, G. (2021); three papers that Karana had written with others colleagues (Ertürkan, H. et al.; Kim, R. et al.; Zhou, J. et al.) on the living material experience (2022); and ´Vernacular biotechnologies' by Hénaff, E. M. (2023).

The paper, 'Evolution of design for sustainability: From product design to design for system innovations and transitions' by Ceschin F. & Gaziulusoy, I. (2016), provided an overview of the evolution of the field of Design for Sustainability (DfS). Their exploration followed "a quasi-chronological pattern" (p.120), and they showed a DfS Evolutionary Framework (p.144) that helped to build ours.

The distinction lies in their emphasis on an approach encompassing sustainability's environmental, socio-ethical, and economic dimensions. In contrast, our objective was to present a timeline (fig.10) showcasing the significant publications of each bio-term examined.

BIO-TERMS TIMELINE

from 1969_1979

- **1969** — **Fuller, B.** Operating Manual For Spaceship Earth
- **1970(72)** — **Papanek, V.** Design for the Real World: Human Ecology and Social Change'
- **1971** — **Maldonado, T.** Design, Nature & Revolution: Toward a Critical Ecology
- **1972** — **Maturana, H. & Varela, F.** Autopoiesis and Congition: The Realization of the Living
- **1973** — **Fromm, E.** The Anatomy of Human Destructiveness
- **1975** — **Lee-Smith, D., Gloster, M.,** Eco-design project
- **1979** — **Lovelock, J. E.** Gaia: A new look on Life on Earth

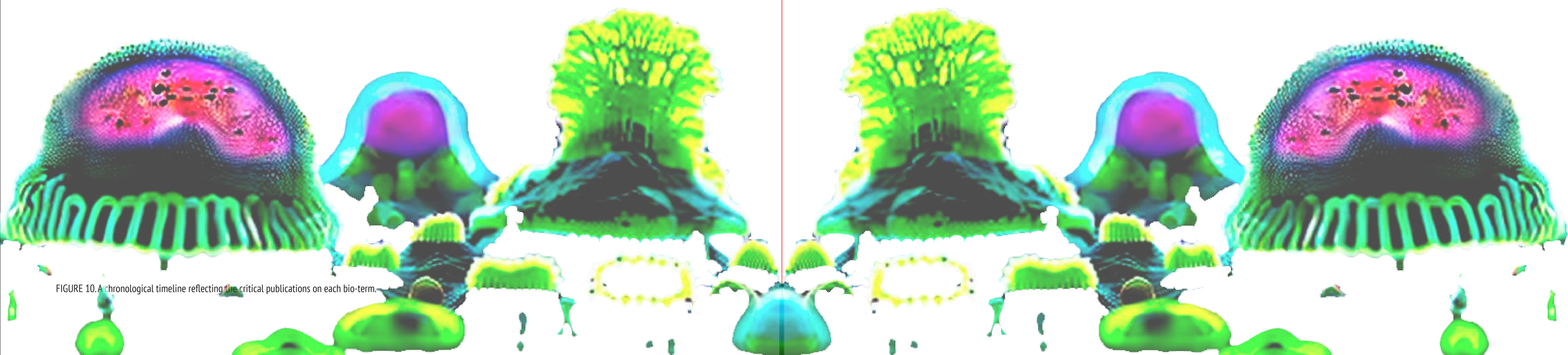


FIGURE 10. A chronological timeline reflecting the critical publications on each bio-term.

BIO-TERMS TIMELINE

from 1989_1999

1980

Maturana, H. R.; Varela, F. J.
Autopoiesis and Cognition: The Realization of the Living

1984

Wilson, E. O.
Biophilia

1987

WCED
Report of the World Commission on Environment and Development: Our Common Future (Brundtland Report)

1989

Frosch, R.A. and Gallopoulos, N.E.
Strategies for Manufacturing

1992

Alper, M.
Biology and Materials? Part I.

1994

Fritz, M., et.al.
Flat pearls from biofabrication of organized composites on inorganic substrates.

1996

Eckardt, M. H.
Fromm's Humanistic Ethics and the Role of the Prophet

Zaremba, C. M., et.al.
Critical transitions in the biofabrication of abalone shells and flat pearls.

1997

Benyus, Janine M..
Biomimicry: Innovation Inspired by Nature

Brezet, J. C. and Hemel, C. G.
Ecodesign: A promising approach to sustainable production and consumption.

1999

Manzini, E.
Strategic Design for Sustainability: Towards a New Mix of Products and Services

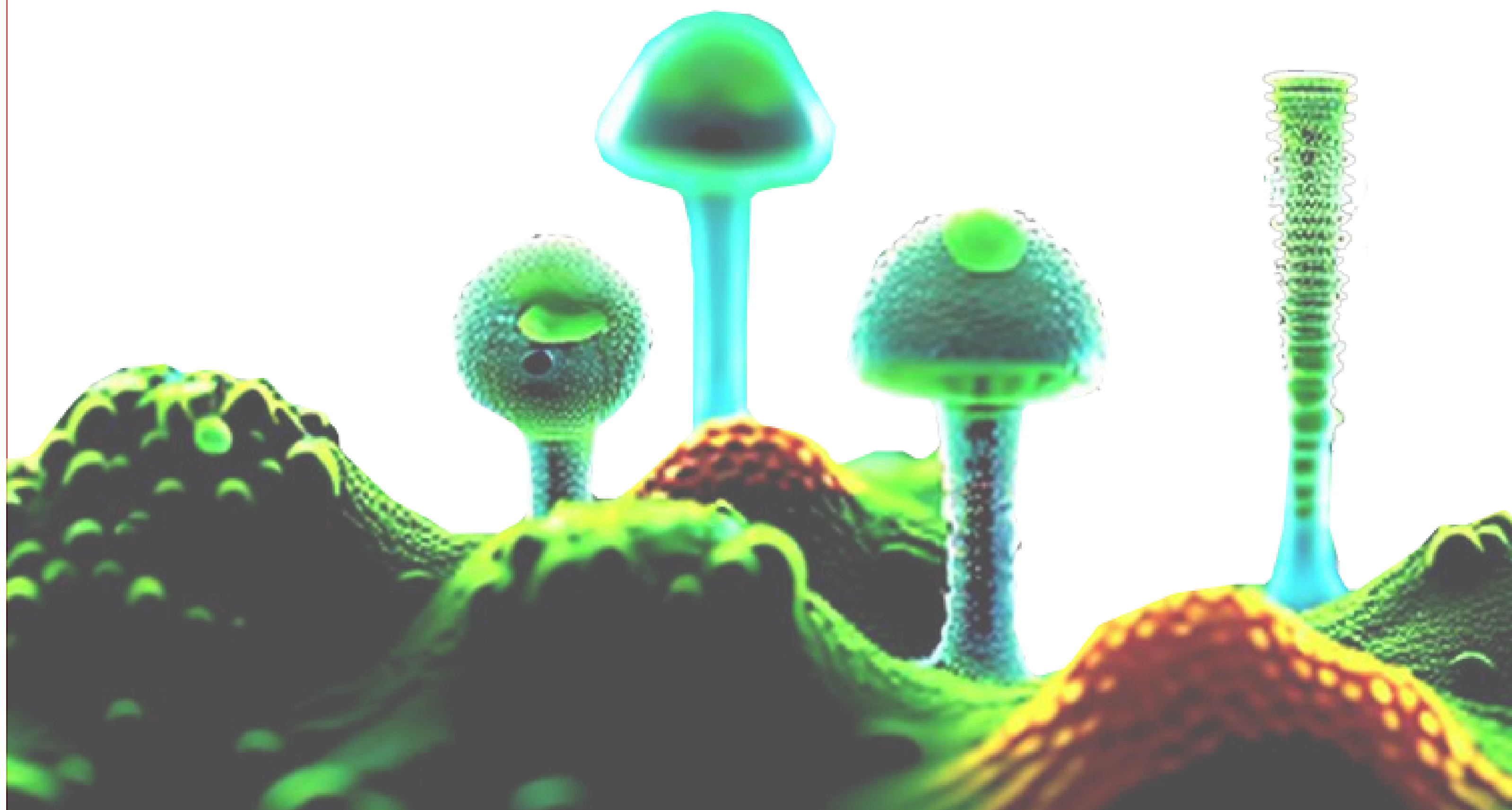


FIGURE 10. A chronological timeline reflecting the critical publications on each bio-term.

BIO-TERMS TIMELINE

from 2000_2009

2000

Ingold, T.
The Perception of the Environment: Essays on Livelihood, Dwelling and Skill

Cross, N.
Engineering Design Methods: Strategies for Product Design

2001

Stevels, A.
Application of Ecodesign: Ten Years of Dynamic Development.

Charter, M., & Tischner, U.
Sustainable Solutions: Developing Products and Services for the Future

2002

McDonough, W., Braungart, M.
Cradle to Cradle: Remaking the Way we Make Things

Van Hemel, C., Cramer, J.,
Barriers and stimuli for Ecodesign

2003

Vezzoli, C.
A new generation of designers: perspectives for education and training in the field of sustainable design

Manzini, E.; Vezzoli, C.
A strategic design approach to develop sustainable product service systems: examples taken from the 'environmentally friendly innovation' Italian prize.

2004

Wu, L. Q., & Payne, G. F.
Biofabrication: using biological materials and biocatalysts to construct nanostructured assemblies

2005

DIRECTIVE 2005/32/EC
Tackara, J. In the Bubble: Designing in a Complex World.

Lee, S.
Fashioning the Future: Tomorrow's Wardrobe.

Reap, J., Baumeister, D., Bras, B.
Holism, Biomimicry and Sustainable Engineering

2006

Mironov, V., Reis, N., & Derby, B.
Bioprinting: a beginning.

2007

Glavic, P., Lukman, R.
Review of sustainability terms and their definitions

2008

Schröder, H. C., Wang, X., Tremel, W., Ushijima, H., & Müller, W. E.
Biofabrication of biosilica-glass by living organisms

Kellert, S., Heerwagen, J., Mador, M.
Biophilic design: The theory, science and practice of bringing buildings to life.

2009

Mironov, V., et. al
Biofabrication: a 21st century manufacturing paradigm

Vincent, J.F.V.
Biomimetics - a review.

Kawade, Y.
On the Nature of the Subjectivity of Living Things

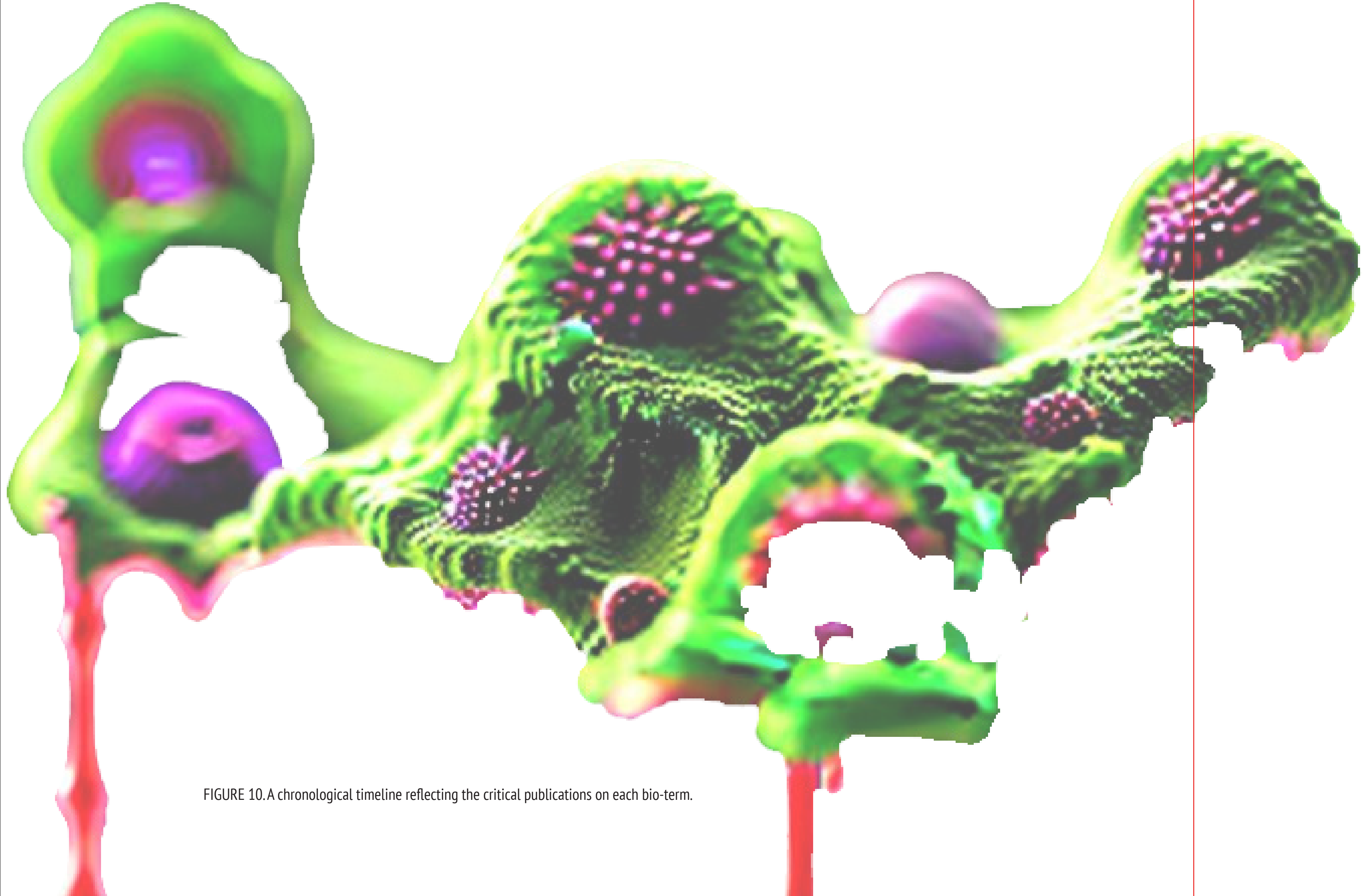


FIGURE 10. A chronological timeline reflecting the critical publications on each bio-term.

BIO-TERMS TIMELINE

from 2010_2016

2010

Oxman, N.
Material-based design computation

Zenios, S.; Makower, J.; Yock, P.
Biodesign: The Process of Innovating Medical Technologies.

Kirksey, Stefan, and Stefan Helmreich.
The emergence of multispecies ethnography

Carlson, R.
Biology Is Technology: The Promise, Peril, and New Business of Engineering Life

2011

Trifonov, E. N.
Vocabulary of Definitions of Life Suggests a Definition

Lee, S.
Grow your own clothes

2012

Myers, W.
Biodesign: Nature, Science, Creativity.

Ingold, T.
Toward an ecology of materials.

Luo, X.
Biofabrication in microfluidics: a converging fabrication paradigm to exploit biology in microsystems

Kuznetsov, S., Taylor, A. S., Regan, T., Villar, N., & Paulos, E.
At the seams: DIYbio and opportunities for HCI

Nimkulrat, N.
Hands-on intellect: integrating craft practice into design research

2013

Collet, C.
This is alive.

Kohn, E.
How forests think: Toward an Anthropology Beyond the Human

Parkers, A.; Dickie, C.
A biological imperative for interaction design.

Ciuffi, V.
Growing Design

De Pauw, I., Karana, E., Kandachar, P.
Cradle to Cradle in Product Development: A Case Study of Closed-Loop Design

2014

Baumeister, D., et al.
Biomimicry Resource Handbook: A Seed Bank of Best Practices.

Ginsberg, A. D., et. al.
Synthetic Aesthetics: Investigating Synthetic Biology's Designs on Nature.

Morris, B.
Anthropology, Ecology, and Anarchism: a Brian Morris Reader.

2015

ISO/TC266
Biomimetics - Terminology, concepts and methodology

Rognoli, V.; Bianchini, M.; Maffei, S.; Karana, E.
DIY materials.

Oxman, N.
Design at the intersection of technology and biology. TED Talk

2016

Pavlovich, M. J.; Hunsberger, J.; Atala, A.
Biofabrication: a secret weapon to advance manufacturing, economies, and healthcare.

Montalti, M.
The Growing Lab.

Hallam, E., Ingold, T.
Making and Growing: Anthropological Studies of Organisms and Artefacts.

Ceschin F.; Gaziulusoy, I.
Evolution of design for sustainability: From product design to design for system innovations and transitions.

Groll, J. et al.
Biofabrication: reappraising the definition of an evolving field.

Pini, M. P.
Biodesign: experiências no exterior e uma proposta para a Escola Politécnica

Giaccardi, Elisa, Nazli Cila, Chris Speed, and Melissa Caldwell.
Thing Ethnography: Doing Design Research with Non-Humans.

Pawlyn, M.
Biomimicry in Architecture.

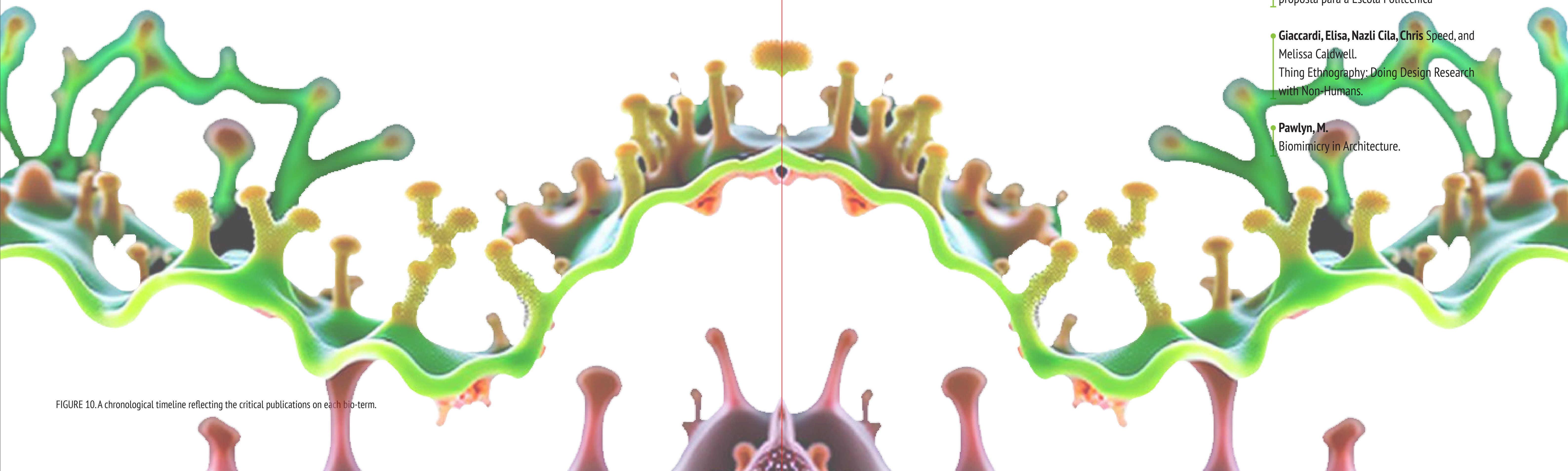


FIGURE 10. A chronological timeline reflecting the critical publications on each bio-term.

BIO-TERMS TIMELINE

from 2016_2023

2017

Kennedy, E. B.
Biomimicry: Design by analogy to biology.

Camere, S.; Karana, E.
Growing materials for product design

Moisy, A., Pschetz, L.,
Designing with living organisms.

Smith, N.; Bardzell, S.; Bardzell, J.
Designing for Cohabitation: Naturecultures, Hybrids, and Decentering the Human in Design

2018

Camera, S., & Karana, E.
Experiential Characterization of Materials: toward a toolkit.

Camere, S., & Karana, E.
Fabricating materials from living organisms: An emerging design practice.

Karana, E.; Blauwhoff, D.; Hultink, E.-J.; Camere, S.
When the material grows: A case study on designing (with) mycelium-based materials.

Myers, W.
Biodesign: From Inspiration to Integration. Exhibition catalog

Antonelli, P. (2018).
Vital Design. In W. Myers (Ed.), Biodesign: Nature, Science, Creativity. (Exp. rev)

Ginsberg, A. D., & Chieza, N.
Editorial: Other Biological Futures.

Esat, R., & Ahmed-Kristensen, S.
Classification of bio-design applications: towards a design methodology.

Franklin, K. and Till, C.
Radical matter: rethinking materials for a sustainable future.

2019

Collet, C.
Biodesign | maat extended.

Karana, E.; Nimkulrat, N.; Giaccardi, E.; Niedderer, K.; Fan, J.-N.
Alive. Active. Adaptive: Experiential Knowledge and Emerging Materials.

Clarke, R.; Heitlinger, S.; Light, A.; Forlano, L.; Foth, M.; DiSalvo, C.
More-than-human participation: design for sustainable smart city futures.

Coulton, P., & Lindley, J. G.
More-than human centred design: Considering other things.

Aktaş, B. M., & Mäkelä, M.
Negotiation between the maker and material: Observations on material interactions in felting studio.

Bezerra, U.T.; Ferreira, H.S.; Barbosa, N.P.
Bio-Inspired Materials.

Buckminster-Fuller, R. López-Pérez, D.
Buckminster Fuller:
Pattern-Thinking.

Polites, M.
The Rise of Biodesign: Contemporary Research Methodologies for Nature-Inspired Design on China.

Watson, J.
Lo-TEK Design by Radical Indigenism.

Clarke, R.; Heitlinger, S.; Light, A.; Forlano, L.; Foth, M.; DiSalvo, C.
More-than-human participation: design for sustainable smart city futures.

2020

Karana, E.
Still Alive: Livingness as a Material Quality in Design

Karana, E.; Barati, B.; Giaccardi, E.
Living artefacts: Conceptualizing livingness as a material quality in everyday artefacts.

Karana, E.; Rognoli, V.; Jacob-Dazarola, R.
The Role of Design in the Development of New Materials: Interview with Elvin Karana.

Antonelli, P.; Oxman, N.
Neri Oxman: Material Ecology.

Arruda, Amilton (Org.).
Biônica e Design**.**

Wang, Y.; Naleway, S. E.; Wang, B.
Biological and bioinspired materials: Structure leading to functional and mechanical performance.

Dade-Robertson, Martin.
Living Construction.

Ceschin, F.; Gaziulusoy, I.
Design for Sustainability: A Multi- level Framework from Products to Socio-technical Systems.

Soboyejo, Wole; Daniel, Leo.
Bioinspired Structures and Design

Collet, C.
Designing our future bio-materiality.

2021

Collet, C.
Designing our future bio-materiality.

Budholiya, S.; Bhat, A.; Raj, S.A.; Hameed Sultan, M.T.; Md Shah, A.U.; A. Basri, A.
State of the Art Review about Bio-Inspired Design and Applications: An Aerospace Perspective.

2022

Ertürkan, H. Karana, E., Mugge, R.
“Is this alive?”: towards a vocabulary for understanding and communicating living material experiences.

Kim, R., Zhou, J., Groutars, E.G., and Karana, E.
Designing living artefacts: Opportunities and challenges for biodesign.

Sayuti, N., Sommer, B., & Ahmed-Kristensen, S.
Biomaterials in Everyday Design: Understanding Perceptions of Designers and Non-Designers.

Zhou, J.; Barati, B.; Giaccardi, E.; Karana, E.
Habitabilities of Living Artefacts: A Taxonomy of Digital Tools for Biodesign.

Grushkin, Daniel (Ed.)
Grow the Future: Visions of Biodesign.

Bandoni, A.; Almendra, R.; Forman, G.
Interdisciplinarity and Collaboration – A Study Focusing on Experienced Biodesign Practitioners.

2023

Hénaff, E. M.
Vernacular biotechnologies

NSF-Funded.
Bio-inspired Design Workshop Report.

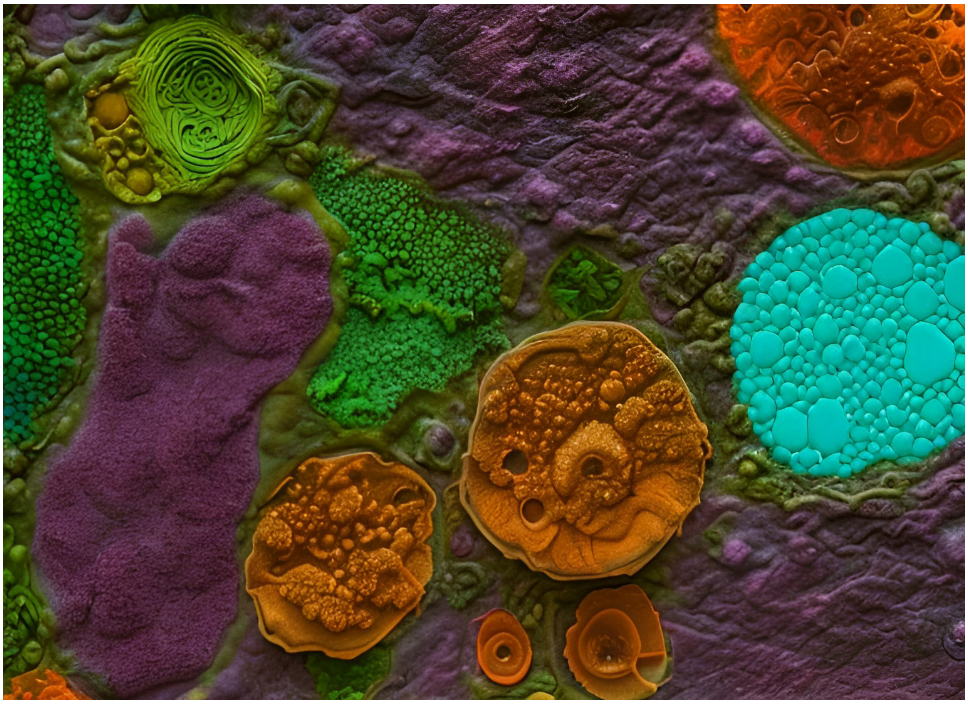
Crawford, Assia.
Designer’s Guide to Lab Practice.

CONCLUSIONS

This initial research has provided a comprehensive systematic literature review concerning Biodesign and its associated terminologies. The study serves as a valuable contribution to identifying and exploring pertinent scholarly works, with the primary objective of establishing a chronological timeline that effectively encapsulates the pivotal publications on each investigated bio-concept, narrowing our focus by excluding the architectural and the health technology field.
See Annex_2 and Annex _3

Biodesign, which integrates design principles with biological sciences, has experienced significant growth in recent years, highlighting the significance of interdisciplinary advancements in material development. These emerging biofabrication technologies, inspired by biotechnology, are progressively recognized as promising and environmentally-friendly approaches toward achieving cleaner production methods.

The intention is to extend the research efforts by expanding the chronological timeline to comprehensively examine the emergence of new concepts and their respective origins. This endeavor aims to enhance our understanding of the evolution and introduction of these novel ideas within the field.



REFERENCES

Alper, M. (1992). Biology and Materials? Part I. MRS Bulletin, 17(10), pp. 24–26.

Blanco-Wells, G. (2021). Ecologies of Repair: A Post-human Approach to Other-Than Human Natures. Frontiers in Psychology, 12. https://doi.org/10.3389/fpsyg.2021.633737

Benyus, Janine M. (1997). Biomimicry: Innovation Inspired by Nature. William Morrow.

Brundtland, G.H. (1987). Our Common Future: Report of the World Commission on Environment and Development. Geneva, UN-Dokument A/42/427.

Camere, S. & Karana, E. (2018). Fabricating materials from living organisms: An emerging design practice. Journal of Cleaner Production, 186, 570-584, https://doi.org/10.1016/j.jclepro.2018.03.081

Ceschin F. & Gaziulusoy, I. (2016). Evolution of design for sustainability: From product design to design for system innovations and transitions. Design Studies, 47, 118-163, https://doi.org/10.1016/j.destud.2016.09.002

Collet, C. (2013). This is Alive. Retrieved 05/02/2022 from http://thisisalive.com/

Collet, C. (2020). Designing our future bio-materiality. AI and Society. https://doi.org/10.1007/s00146-020-01013-y

Ertürkan, H.; Karana, E.; Mugge, R. (2022). "Is this alive?": towards a vocabulary for understanding and communicating living material experiences. DRS 2022. https://doi.org/10.21606/drs.2022.796

Esat, R. & Ahmed-Kristensen, S. (2018). Classification of bio-design applications: towards a design methodology. In DS 92: Proceedings of the DESIGN 2018 15th International Design Conference, 1031-1042.

Escobar, A. (2018). Designs for the Pluriverse: Radical Interdependence, Autonomy and the Making of Worlds. Duke University Press.

Fink, A. (1998). Conducting Research Literature Reviews: From the Internet to Paper. Sage Publication.

Fritz, M., Belcher, A.M., Radmacher, M., Walters, D.A., Hansma, P.K., Stucky, G.D., Morse, D.E. & Mann, S. (1994) 'Flat pearls from biofabrication of organized composites on inorganic substrates', Nature, 371(6492), pp. 49–51.

Fuller, B. (1969). Operating Manual for Spaceship Earth. Touchstone Books. https://doi.org/10.21278/idc.2018.0531

Lovins, A. (2001). Natural Capitalism. Australian Broadcasting Corporation, [online] Available at: http://www.abc.net.au/science/slab/natcap/default.htm

Karana, E., de Pauw, I., Kandachar, P., & Peck, D. (2010). Nature Inspired Design: strategies towards sustainability. ERSCP-EMSU Conference.

Karana, E., Barati, B., Rognoli, V., & van der Laan, A. Z. (2015). Material driven design (MDD): A method to design for material experiences. International Journal of Design, 9(2), 35–54.

Karana, E., Barati, B., & Giaccardi, E. (2020). Living artefacts: Conceptualizing livingness as a material quality in everyday artefacts. International Journal of Design, 14(3), 37–53.

Kim, R., Zhou, J., Groutars, E.G., and Karana, E. (2022). Designing living artefacts: Opportunities and challenges for biodesign, in Lockton, D., Lenzi, S., Hekkert, P., Oak, A., Sádaba, J., Lloyd, P. (eds.), DRS2022: Bilbao, 27 June - 3 July, Bilbao, Spain. https://doi.org/10.21606/drs.2022.942

Koivumen, H. (2005). Bio Design Products: Co-Design with Nature. Joining Forces, 4. University of Art and Design Helsinki. http://www.uiah.fi/joiningforces/papers/Koivunen.pdf.

Ingold, T. (2000). The Perception of the Environment: Essays on Livelihood, Dwelling and Skill. Routledge.
ISO/TC266 (2015). Biomimetics - Terminology, concepts and methodology. [online] ISO. Available at: https://www.iso.org/obp/ui/#iso:std:iso:18458:ed-1:v1:en (accessed: 04.03.2018).

Kohn, E. (2013). How forests think: Toward an Anthropology Beyond the Human. Univ of California Press.

Lee-Smith, D. & Gloster, M. (1975). Eco-design project. DMG-DRS J., 9, 259-264.

Lovelock, J. (1979). The Ages of Gaia: a Biography of Our Living Earth. Bantam Books.

Maldonado, T. (1970/72). Design, Nature & Revolution: Toward a Critical Ecology. Harper & Rowe.

Manzini, E. (1999). Strategic Design for Sustainability: Towards a New Mix of Products and Services, Ecodesign '99. Tokyo, Japan, February.

McDonough, W. & Braungart, M. (2002). Cradle to Cradle: Remaking the Way we Make Things. North Point Press.

Meadows, D. H. et al. (1972). The Limits to Growth: a Report for the Club of Rome's Project on the Predicament of Mankind. New York: Universe Books.

Mironov, V., Reis, N., & Derby, B. (2006). Bioprinting: a beginning. Tissue engineering, 12(4), 631-634.

Mironov, V. et al. (2009). Biofabrication: a 21st century manufacturing paradigm. Biofabrication, 1(2). DOI 10.1088/1758-5082/1/2/022001

Moisy, A. & Pschetz, L. (2017). Designing with living organisms. In: Proceedings of the 3rd Biennial Research through Design Conference, pp. 323-339. https://doi.org/10.6084/m9.figshare.4746994. Edinburgh, UK, 22-24 March 2017.

Myers, W. (2018). Bio Design: Nature + Science + Creativity. The Museum of Modern Art.

Oxman, N. (2015). Design at the intersection of technology and biology. TED Talk, Retrieved November 3, 2016, from https://www.ted.com/talks/neri_oxman_design_at_the_intersection_of_technology_and_biology?language=en

Papanek, V. (1970/72). Design for the Real World. Bantam Book.

Pavlovich, M. J., Hunsberger, J., & Atala, A. (2016). Biofabrication: a secret weapon to advance manufacturing, economies, and healthcare. Trends in Biotechnology, 34(9), 679–680. https://doi.org/10.1016/j.tibtech.2016.07.002

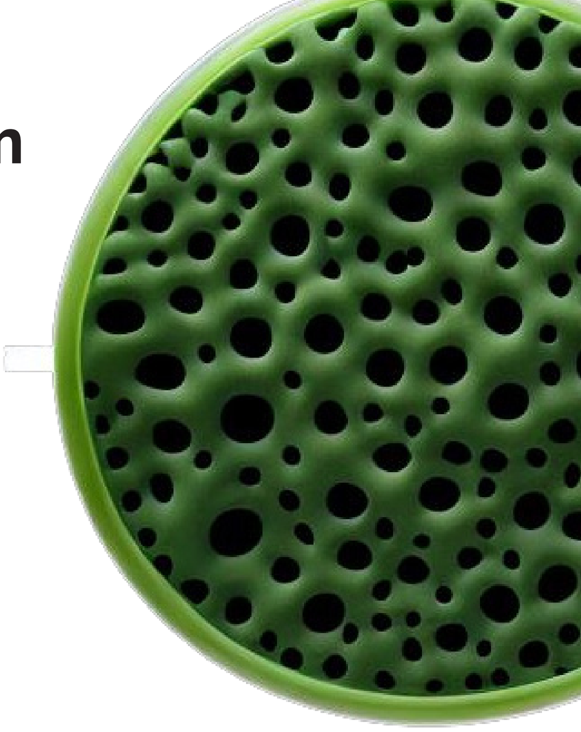
Rognoli, V.; Bianchini, M.; Maffei, S.; Karana, E. (2015). DIY materials. Materials & Design, 86, 692-702, https://doi.org/10.1016/j.matdes.2015.07.020

Vezzoli, C. A. (2008) Design for Environmental Sustainability - Life Cycle Design of Products. Springer London. https://doi.org/10.1007/978-1-4471-7364-9

Wilson, E. O. (1984). Biophilia. Harvard University Press.

Zhou, J.; Barati, B.; Giaccardi, E.; Karana, E. (2022). Habitabilities of Living Artefacts: A Taxonomy of Digital Tools for Biodesign. International Journal of Design, 16(2), 57-73. https://doi.org/10.57698/v16i2.05

Report Conclusion



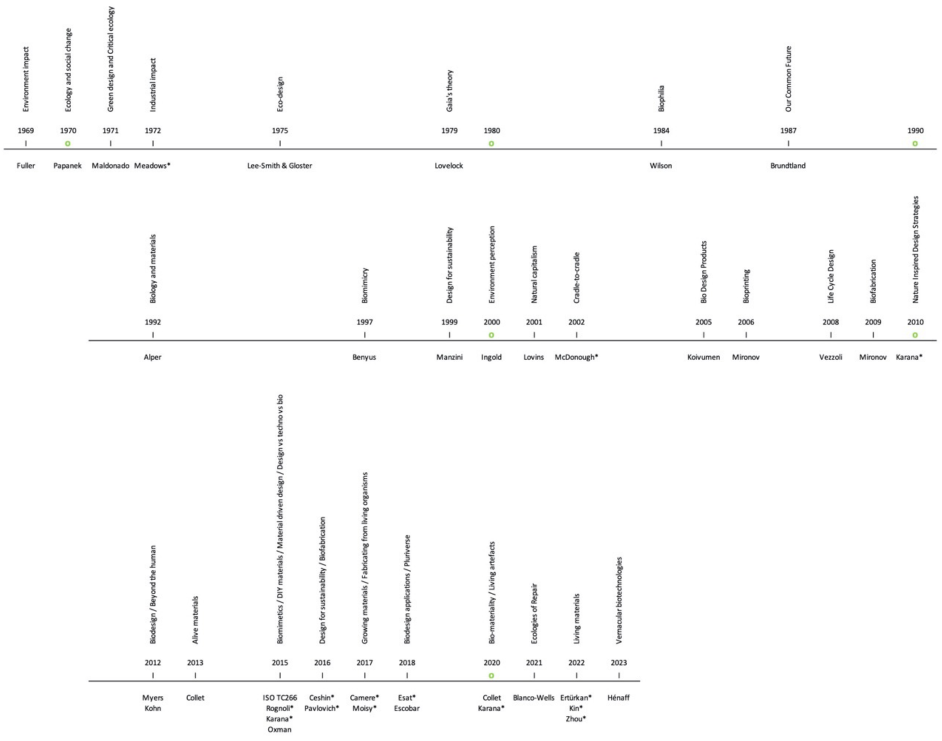
This initial report sets the stage for co-creation, in alignment with the project team, and for the development of work packages. It also provides a brief for developing and validating policy proposals at the Helsinki workshop.

Concerning the Biodesign policy making, as stated in the chapter conclusion, there is a long way to go. We identified the main gaps that can be the insights to "set scene" for the Helsinki workshop dynamics with academics, citizens, students, industry representatives and policy making institutions.

The Biodesign synthesis timeline and Cocoon's Bioterms framework are important building blocks for the future project development. Has stated in the Bioterms chapter conclusion, Biodesign, which integrates design principles with biological sciences, has experienced significant growth in recent years, highlighting the significance of interdisciplinary advancements in material development. These emerging biofabrication technologies, inspired by biotechnology, are progressively recognized as promising and environmentally friendly approaches toward achieving cleaner production methods that need to be integrated in the educational courses design as well as in VET training programs.

This initial achievements will be relevant to framework the following deliverables, mainly the D2.2 where we will map the Fablab scenes, the Biodesign innovative initiatives and the existing Greenlabs.

FIGURE 11. A chronological timeline synthesis



ANNEX

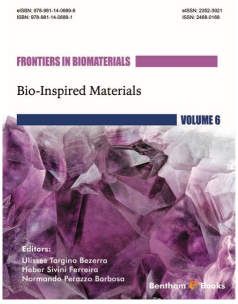
ANNEX 1_TABLE: Recommendations from the European Union report 'Design for Growth and Prosperity' (from Patrocinio, 2013, p. 111-112; based on Thomson and Koskinen, 2012, p.8-11)

	STRATEGIC ACTIONS	RECOMMENDATIONS
1.	Differentiating European design on the global stage	1. Identify and strengthen existing 'European centres of design excellence' in business and industry and provide means for those to collaborate in open networks that drive innovation into Europe's whole industrial ecosystem.
		2. Promote the increased use of design in European industry to encourage synergies in support of economic growth, environmental regeneration, and the raising of social and emotional value, whilst respecting the need for renewable and endogenous resources.
		3. Work towards zero tolerance of infringement. This requires legislative revision, through the inclusion of a 'Duty of Care' for shared responsibilities on IPR protection across the digital value chain. Set up a specific EU Tribunal /Court for European IP cases and promote and increase the training of judges in national courts, in relation to the protection of Intellectual Property Rights in the physical world and online.
		4. Create a 'Designed in the European Union' label in connection with the European ECOLABEL to stimulate the export of design services. The intention is to make the protection and enforcement of European design and innovation more effective and accessible, whilst at the same time raising the bar on expectations and associating excellence with sustainability.
2.	Positioning design within the European innovation system	5. Continue to support and expand the work needed to develop more effective and reliable methods for measuring the impact of investment in design on growth and social well-being, at the micro and macro levels, and include these within European innovation statistics.
		6. Enforce the implementation of the current NACE Code 74:10 for Specialised Design Activities by all Member States and ensure updating as necessary for benchmarking and comparative analysis across member states.
		7. Include design within innovation and business incubators and their networks.
		8. Create guidelines, codes of practice, legal frameworks and experimental spaces to promote the use of Open Design.
		9. Develop a European policy that ensures a more sophisticated approach to the public procurement of innovative solutions through the recognition, inclusion and implementation of design as a driver of user-centred innovation.
		10. Improve access to design management expertise and tools for companies across Europe to support the uptake and integration of design and design management as a strategic tool for growth.

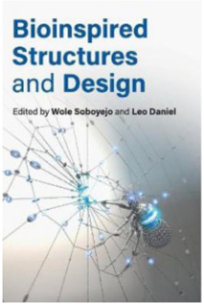
	STRATEGIC ACTIONS	RECOMMENDATIONS
3.	Design for innovative and competitive enterprises	11. Establish a pan-European design leadership programme that ensures Europe's next generation of large companies have at their top, leaders who are design aware and more inclined to make better use of design.
		12. Develop programmes that support European medium-sized companies with ambitions to grow into large design-led companies through design innovation.
		13. Establish mechanisms whereby design knowledge and best-practice transfer can be more effectively enabled between large, design-led companies, academia and SMEs.
		14. Strengthen design innovation in SMEs through taking into account the specific needs of SME's within EU programmes such as Horizon 2020 and improve their access to member state level programmes.
		15. Recognise and value apprenticeships and vocational training for generating world-class specialist and skilled crafts-people in traditional and emerging sectors with an increased awareness of design, as a driver of growth and job creation.
4.	Design for an innovative public sector	16. Increase the use of design/designers in public sector innovation:
		// Through establishing a Design Lab within the Commission to run small-scale demonstration projects showing the value of design-led public sector innovation.
		// Through supporting designers' greater involvement in 'living labs' where social innovation and public services are critical challenges.
		// Through exploiting the potential of the European Structural Funds, in particular the European Regional Development Fund, on design innovation for social change across policy areas.
		17. Build the capacity of public sector administrators to use design methods themselves and to procure design effectively:
		// Through design toolkits, case studies and designers in residence for EU institutions and Member States and regions.
		// Through developing a design curriculum for public administrators' education and professional development, with attendant Master Classes in design for effective policy-making and procurement.

	STRATEGIC ACTIONS	RECOMMENDATIONS
5.	Positioning design research for the 21st century	18. Embed design research in Europe's research system in order to create new knowledge that will enhance innovation whilst in parallel evaluating, on an on-going basis, the value of design in the Horizon 2020 programme:
		// Through including design researchers in cross-sectoral, multidisciplinary research programmes addressing global challenges such as climate change, food security and health and well-being.
		// Through funding the evaluation and communication of the value of design in the Horizon 2020 Programme.
		19. Create a European network on design research at the European level to foster greater exchange amongst diverse actors and to encourage and enhance research that supports European design innovation capacity.
6.	Design competencies for the 21st century	20. Raise the level of design literacy for all the citizens of Europe by fostering a culture of design learning for all at every level of the education system.
		21. Encourage Member States to support the development of design competencies for the 21st century:
		// Through embedding the strategic Executive Summary role of design across disciplines in higher education
		// Through strengthening continuing professional development programmes for design professionals.
		// Through embedding design in the training of apprentices.

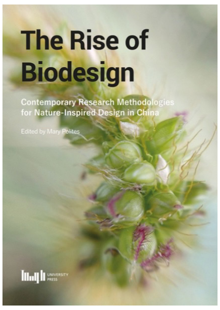
ANNEX 2_ LIST: Recommended readings



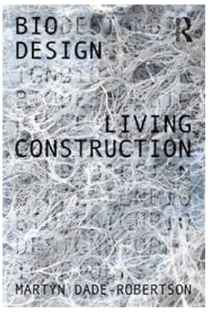
Bezerra, U.T.; Ferreira, H.S.; Barbosa, N.P. (2019). Bio-Inspired Materials. Sharjah: Bentham Books. DOI:10.2174/9789811406 8981190601



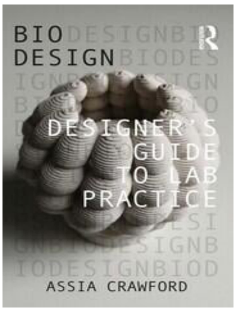
Soboyejo, Wole; Daniel, Leo. (2020). Bioinspired Structures and Design. Cambridge: Cambridge University Press. ISBN: 978110701558



Polites, Mary (Ed.). (2019). The Rise of Biodesign: Contemporary Research Methodologies for Nature-Inspired Design on China. Beijing: Tongji University Press. ISBN 9787560881898

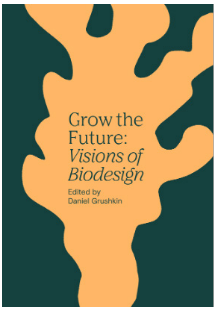


Dade-Robertson, Martin. (2020). Living Construction. London: Rotledge. ISBN 9781138363038



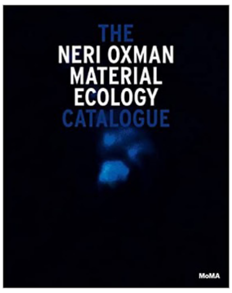
Crawford, Assia. (2023). Designer's Guide to Lab Practice. London: Routledge. ISBN 9781032426846

(Release date: September 2023)

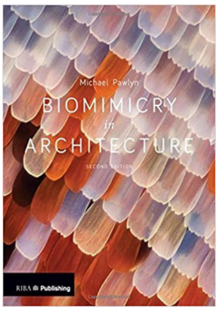


Grushkin, Daniel (Ed.) (2022). Grow the Future: Visions of Biodesign. Shenzen: PrintNinja. ISBN 9781635320046

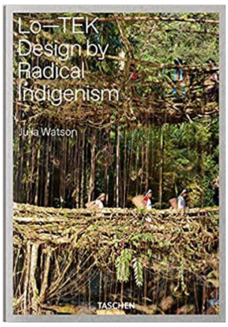
Myers, W. (2018). Bio Design: Nature + Science + Creativity. New York: The Museum of Modern Art. ISBN 9781633450714



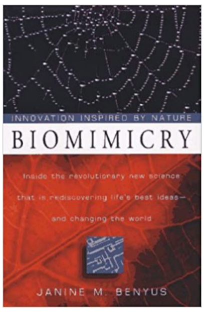
Antonelli, P.; Oxman, N. (2020). Neri Oxman: Material Ecology. New York: The Museum of Modern Art. ISBN 9781633451056



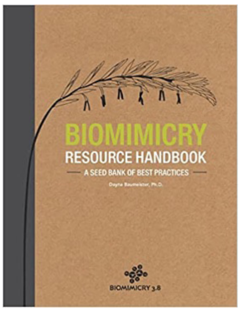
Pawlyn, M. (2016). Biomimicry in Architecture. London: RIBA Publishing. ISBN 9781859466285



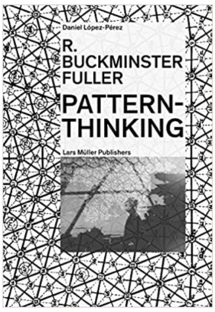
Watson, Julia. (2019) Lo-TEK Design by Radical Indigenism. Berlin: Taschen. ISBN 9783836578189



Benyus, Janine M. (1997). Biomimicry: Innovation Inspired by Nature. New York: William Morrow. ISBN 9780688136918



Baumeister, D.; Tocke, R. et al (2014). Biomimicry Resource Handbook: A Seed Bank of Best Practices. CreateSpace Independent Publishing Platform. ISBN 9781505634648



Buckminster-Fuller, R. López-Pérez, D. (2019) R. Buckminster Fuller: Pattern-Thinking. Zurich: Lars Müller Publishers. ISBN 9783037786093

Arruda, Amilton (Org.). (2020). Biônica e Design. São Paulo: Blucher. ISBN 9858580394214

ANNEX 2_10 main quotes

•1997

“Biomimicry is innovation inspired by nature. In a society accustomed to dominating or ‘improving’ nature, this respectful imitation is a radically new approach, a revolution really. Unlike the Industrial Revolution, the Biomimicry Revolution introduces an era based not on what we can extract from nature, but on what we can learn from her.” (Benyus, J. M., 1997, p.2)

Benyus, Janine M. (1997). Biomimicry: Innovation Inspired by Nature. New York: William Morrow. ISBN 9780688136918

•2009

“Biofabrication can be defined as the production of complex living and non-living biological products from raw materials such as living cells, molecules, extracellular matrices, and biomaterials.” (Mironov, V. et al., 2009, p.2)

Mironov, V.; Trusk, T.; Kasyanov, V.; Little, S.; Swaja, R.; Markwald, R. (2009) Biofabrication: a 21st century manufacturing paradigm. Biofabrication, Volume 1, Number 2. DOI 10.1088/1758-5082/1/2/022001

•2015

“Biomimetics is a creative approach based on the observation of biological systems.” (ISO/TC266, 2015)

ISO/TC266 (2015), Biomimetics - Terminology, concepts and methodology. [online] ISO. Available at: https://www.iso.org/obp/

•2017

“Growing Design’ (Montalti, n.d.; Ciuffi, 2013), which we define as the fabrication of materials and products from living organisms, can be considered as a type of “DIY material practice” (Rognoli, Bianchini, Maffei & Karana, 2015). ‘DIY materials’ are designed and created through individual or collective self-production practices, often by techniques and processes of the designer’s own invention (Rognoli et al., 2015).” (Camere, S.; Karana, E., 2017, p.101)

Camere, S.; Karana, E. (2017). Growing materials for product design. Conference: EKSIG2017 - International Conference on Experiential Knowledge and Emerging Materials, Delft, The Netherlands

•1018

“Biotechnology offers exciting opportunities for novel and more sustainable alternatives for the design and manufacturing of products. One of the most promising approaches is the fabrication of materials from living organisms, such as fungi and bacteria. An increasing number of designers are engaging in this Growing Design practice, exploring the unique potentials of the grown materials for product design.” (Camere, S.; Karana, E., 2018)

Camere, S.; Karana, E. (2018) Fabricating materials from living organisms: An emerging design practice. Journal of Cleaner Production, Volume 186, pp. 570-584, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2018.03.081

2018

"If design is humanity's process for changing present conditions to other, preferred ones (to paraphrase political scientist Herbert Simon), then biodesign – which we broadly define here as the design of, with, or from biology – offers novel perspectives on what change could look like, for ourselves and other living things." ." (Ginsberg, A. D., & Chieza, N., 2018, p.2)

Ginsberg, A. D., & Chieza, N. (2018). Editorial: Other Biological Futures. Journal of Design and Science. https://doi.org/10.21428/566868b5

2018

"Biodesign goes further than other biology-inspired approaches to design and fabrication. Unlike biomimicry, cradle to cradle, and the popular but frustratingly vague 'green design,' biodesign refers specifically to the incorporation of living organisms as essential components, enhancing the function of the finished work. It goes beyond mimicry to integration, dissolving boundaries and synthesizing new hybrid typologies. The label is also used to highlight experiments that replace industrial or mechanical systems with biological processes." (Myers, W., 2018, p.8-9)

Myers, W. (2018). Bio Design: Nature + Science + Creativity. New York: The Museum of Modern Art. ISBN 9781633450714

2019

"Biodesign incorporates the inherent life-conducive principles of biological living systems (cyclic, solar, local) into the design process to transition to a more holistic, sustainable and regenerative future." (Collet, C., 2019)

Collet, C. (2019) Biodesign | maat extended. Disponível em: https://ext.maat.pt/bulletin/biodesign. Acesso em: 16 set. 2021.

2019

"We believe that in the design of living artefacts, it is crucial to empower both designers and users to perpetuate the livingness of the organism through a careful crafting of habitabilities that attends to the mutual well-being of both humans and non-humans. (Karana, E.; et al. 2019, p.4)

Karana, E.; Nimkulrat, N.; Giaccardi, E.; Niedderer, K.; Fan, J.-N. (2019) Alive. Active. Adaptive: Experiential Knowledge and Emerging Materials. International Journal of Design, 13 (2). pp. 1-5. ISSN 1991-3761.

2020

"Today, technological and economic opportunities, alongside its ecological benefits, suggest biodesign as a new industrial paradigm for the production of artefacts in the 21st century." (Karana, E.; et al., 2020, p.37)

Karana, E.; Barati, B.; Giaccardi, E. (2020). Living artefacts: Conceptualizing livingness as a material quality in everyday artefacts. International Journal of Design, 14(3), pp. 37-53.

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