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BIOLOGY AS A SOURCE OF INSPIRATION FOR ARCHITECTURAL INNOVATIONS

BIOLOGIA JAKO ŹRÓDŁO INSPIRACJI DLA INNOWACJI ARCHITEKTONICZNYCH

Abstract

The text presents the contemporary phenomenon of the infiltration of biological sciences into the field of architecture, resulting in the emergence of original and innovative design solutions that address both threads: formal and process. This phenomenon is accompanied by the slow but noticeable acquisition of expressive "shapes of nature" in architecture, which fits into the historical organic model. This model has now taken on a form appropriate to technological progress related to digital changes, determining the research background here. In turn, the scope and method of implementing innovative solutions outline the framework for the analysis, which creates an opportunity for the extrapolation of innovation categories that are new for architecture.

Keywords: biology, organism, bioarchitecture, nature, innovation

Streszczenie

Tekst przedstawia współczesny fenomen przenikania nauk biologicznych w obszar architektury skutkujący pojawianiem się oryginalnych i innowacyjnych rozwiązań projektowych, które dotyczą tak wątków formalnych, jak i procesowych. Zjawisku temu towarzyszy powolne, acz zauważalne, nabywanie przez architekturę eksperymentalną coraz wyrazistszych „kształtów natury", które wpisują się w historyczny już model organiczny. Model ten przybrał współcześnie formę odpowiednią dla postępu technologicznego, związanego z przemianami cyfrowymi, które wyznaczają tutaj tło badawcze. Z kolei zakres i sposób implementacji rozwiązań innowacyjnych nakreślają ramy dla analizy, co stwarza szansę dla podjętej tu ekstrapolacji nowych dla architektury kategorii innowacji.

Słowa kluczowe: biologia, organizm, bioarchitektura, natura, innowacja

1. INTRODUCTION

Let's take as our starting point the idea expressed a hundred years ago by Wassily Kandinsky: "If the artist has outer and inner eyes for nature, nature rewards him by giving him inspiration."[1] It is no different today: living processes observed in the natural world inspire innovative

[1] W. Kandinsky, *My Autobiography*, 1918, p. 14 [after:] F. Whitford, *Kandinsky*, Paul Hamlyn Ltd, London 1967.

solutions in many science and creative fields. Similarly, in design, the fusion of technology with nature results in new ideas that engage architecture in a broader civilizational discourse. This directs designers towards concepts and realisations that have previously been beyond the reach of the workshop and sometimes beyond their imagination. Thanks to technological progress, architects discover new and unexplored territories that could only be a dream in past eras, they adapt new digital methods of design and production derived from various fields of science (biology, chemistry, physics and others), and from design arts. These phenomena cause a kind of convergence in creative thought. A special place in this set of academic disciplines is occupied by biology, specifically by biotechnology and genetics. New scientific discoveries applicable to architecture could be found from these areas. Moreover, they may redefine the contemporary interpretation of the category of mimesis. And although architects have always been inspired by the "shapes of nature", until recently they discovered them mainly in formal similarities. However, now they can discover process similarities as well. The new organic model that accompanies this activity sets out original paths for creative exploration. Innovation is also associated with this – determining the framework for our analysis. And therefore, the consideration presented here aims to focus on this model and to place it in the context of digital changes, in chapter two. The scope of innovation in the context of architecture is then determined in chapter three. This exploration allows us to indicate the novelty in the design experiments discussed in chapter four. In our research we use comparative analysis of individual examples, embedded in a specific historical context – the most recent era, known as digital. In summary, we propose a set of criteria (areas) of innovation, which are included in the final table. As a result of undertaken research, we prove that architecture of the 21st century sometimes draws inspiration from the "shapes of nature," becomes similar to these shapes not only in terms of forms, but also processes.

2. ORGANIC MODEL AND DIGITAL CHANGES

The contemporary roots of the organic model in design are based especially on natural sciences, including: research on inheritance processes conducted in the 19th century by the monk and scientist Gregory Mendel, who described them for the first time in 1866; then by William Bateson, who developed his research and proposed the concept of genetics in 1905; or finally in the Cartesian deformations created by the biologist and mathematician D'Arcy Thompson, who at the beginning of the 20th century showed that evolution is a fundamental determinant of the form and structure of living organisms. In his book *On Growth and Form* from 1917, he analysed the relationships between biological forms and mechanical phenomena, which he described using geometric transformations.[2] However, formal sources of inspiration for the projects discussed here can be found in photographic experiments of the early 20th century, such as time-lapse analyses of the movement of liquids and a bullet cutting through a playing card, which was recorded in 1931 by the American inventor and engineer Edgerton Harold Eugene.[3] Despite these discoveries, the

[2] D.W. Thompson, *On Growth and Form: The Complete and revised edition*, Dover Publications, New York 1992.

[3] *Harold Eugene Edgerton* [in:] Wikipedia, https://en.wikipedia.org/wiki/Harold_Eugene_Edgerton (access: 12.05.2024).

modern organic model did not widely infiltrate the design arts of that time, and was basically absent in architecture, giving way to abstraction. This model became much more widely used after the Second World War, when genetic research was reflected, for example, in Friedrich Kiesler's original concept of *correalism*, according to which man and his environment is a complex holistic system.[4] This thinking was exemplified by his *Endless House project* (1950–1960) (Ill. 1) – a biomorphic single-family house functioning like an organism that combined all spheres of life in one flexible and adaptable habitat. It is also worth mentioning Buckminster Fuller's earlier concept, *Dymaxion House* (1930–1945) (Ill. 2), which was located at the crossroads of design and architecture. The author perceived their own structures in terms of pure prosthetics, where individual elements were perceived as electrical mechanisms, supporting and enhancing the human environment. This kind of approach, combining what is "bio" with what is "mech," found its continuation in the experiments of Archigram connecting the fascination with organic forms and dynamism, also the ability to transform and change over time,[5] as expressed in *Walking City* and *Plug-in-City*.

In the following decades, organic forms, thanks to the application of new material processing technologies, digital prototyping and production, gained a new life. Jan Kaplicky can be considered a contemporary protagonist of experimenting with "natural shapes." In 1986, he was the first to propose the term "blob" to describe an architectural form, which was next developed by Greg Lynn in numerous projects and essays in 1990.[6] Both of them drew on cinematic digital techniques like James Blinn's crucial animation made in 1982 and titled *The Evolution of Blobby Man* (Ill. 3). These techniques were subsequently adapted in 3D graphics software and in cinematography (for example, James Cameron's 1991 film *Terminator 2*). The combination of animation techniques and design art produced new spatial concepts that we now recognize and celebrate as innovative. However, today we are dealing with other areas of science and knowledge that open up new paths where architects can find inspiration.

3. INNOVATION IN THE DESIGN PROCESS

The term "innovation" can be defined as any activity of a scientific, technical, organisational, or commercial nature that aims to implement improvements at multiple levels of creation. When considering the field of architecture, two basic types of such upgrades can be identified: process-based and product-based. The former are related to the bringing of new or significantly improved methods, tools and techniques into the design process. The latter are related to the formal, material and functional issues involved in the creation of a product. The term's genesis can be traced to the 1950s and 1960s, when innovation was conceptualized as a linear model that commenced with research, progressed technologically, and culminated in the introduction of a product to the market. Over time, the linear model has been replaced

[4] A. Sachs (ed.), *Nature Design. From Inspiration to Innovation*, Lars Müller Publishers, Baden 2007, p. 170.

[5] S. Sadler, *Archigram: Architecture without Architecture*, MIT Press, Cambridge, London 2005.

[6] G. Lynn, *Architecture Curvilinearity: The Folded, the Pliant, and the Supple*, "Architectual Design" 1993, no. 63(3/4), pp. 9–15, https://marywoodarchtheory.wordpress.com/wp-content/uploads/2013/10/1993_lynn_curvilinearity.pdf (access: 13.05.2024).

by a non-linear and iterative model that depends on a number of external factors.[7] Since then, a number of definitions and approaches to innovation have been developed, but these will not be discussed here, and for the purposes of our research we will only mention that – in principle – innovation activity is related to creative activity aimed at increasing knowledge resources and using them to create new applications.[8] So why are we leaving out all these other definitions? The answer for architects is significant. We can agree that the parameters in the definitions of innovation[9], originally formulated for economic purposes, do not fully capture the scope and nature of architectural works that could be considered (in their entirety or in some part) a novelty in our discipline. The examples presented in this article illustrate works that go beyond the rigid definition of the term. On the one hand, they are based on the implications of bioengineering research, where areas of innovation are easy to identify. On the other hand, it is also relatively simple to overlook these "undefinable" but equally important areas of the creative process. The sample projects referenced here are analysed through the lens of a microscope, which enables them to be ranked according to the scale: from micro to macro. It should be noted that our focus is not on the formal scale of the target object, but rather on the scale of the processes underlying its formation. Thus, we begin with a study of DNA, then move on to cells, bones, and finally, a mycelial structure, and finish with a plant organism.

4. CASE STUDY

The first example is Greg Lynn's concept – *Embryological House* (Ill. 4), created between 1997–2000 using software (in particular Microstation and Maya) for character modelling and animation. Prototype house objects were produced in several dozen copies using stereolithography and artificial material in milled MDF forms.[10] The architect's vision is to create an unlimited differentiation of simple spatial arrangements. The house model is based on a series of twelve control points applied to a previously established geometry that sets the framework for the project. Lynn explores the potential of "prefabricating" a personalised habitat, based on guidelines provided by future users. He uses generative design techniques to transform the form in an iterative process, similar to biological evolution and DNA sequence changes. From a usability perspective, mutation offers the potential to modify shape in order to adapt to changing user needs and environmental conditions. And from a process perspective, mutation allows us to create personalised objects from a single group of houses-embryos.

Let us dive into the cellular development and explore the possibilities of cultured meat as a building block. *In Vitro Meat Habitat* (Ill. 5), created in 2009 by Terreform One, represents

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[7] B. Godin, *The Linear Model of Innovation: The Historical Construction of an Analytical Framework*, "Science, Technology, & Human Values" 2006, vol. 31, pp. 639–667. DOI: 10.1177/0162243906291865 (access: 29.04.2024).

[8] J. Witecka (ed.), *Podręcznik Frascati. Proponowane procedury standardowe dla badań statystycznych w zakresie działalności badawczo-rozwojowej*, published in agreement with the OECD (Organisation for Economic Co-operation and Development), Warszawa 2006, p. 34.

[9] L. Białoń, *Zręby teorii innowacji* [in:] L. Białoń (ed.), *Zarządzanie działalnością innowacyjną*, Placet, Warszawa 2010, pp. 12–20.

[10] H. Shubert, *Embryological House* [in:] Canadian Centre for Architecture, https://www.cca.qc.ca/en/articles/issues/4/origins-of-the-digital/5/embryological-house (access: 1.06.2024).

a conceptual design for a home based on meat cells grown in a laboratory.[11] The main goal of the project is to create an autonomous environment that would enable the fabrication of building materials for housing. The culture process is initiated by the collection of muscle cells from a living animal.[12] These cells are subsequently stored under controlled conditions, wherein they assume an architectural-like shape and structure. The designer's aim is to consider the potential for replacing conventional buildings in the future with organic structures that would possess the ability for self-healing and self-regulation, such as regulating all window and door openings by muscle contractions.[13] The shape and the physical properties of such a living house would be designed with the specific needs of the inhabitants in mind, and would be able to adapt to changing environmental conditions.

Increasing the scale of the studied processes, we will now consider a third example based on bones. In this case, we analyse the chair by Joris Laarman, *Bone Chair* (2006) (Ill. 6), created as a dynamically evolving bone skeleton that adapts its structure, thickness, and shape to environmental conditions. At the conceptual level, Laarman used a design tool for optimising the production of automotive parts that had been developed by the International Developed Centre Adam Opel AG[14] research group. This tool allowed him to design the furniture in a way that it would achieve the maximum strength with a minimum amount of material.[15] The chair's prototype was cast in one piece from aluminium, eliminating all welds and material defects that would limit its organic shape. According to the designer, the final effect consisted of a comprehensive design and production cycle that resulted in the creation of a sculptural form: "By using digital tools to mimic natural growth processes, we can create objects that are both highly efficient and visually stunning. Bone Chair is a perfect example of how technology and nature can come together to push the boundaries of design."[16]

The next example is based on the processes occurring in mycelium, which has unique properties and roles in ecosystems that are of interest of designers due to their potential applications in architecture. David Benjamin's *Hy-Fi* project (2014) (Ill. 7) is a twelve-meter construction of three cylindrical towers built of mushroom-bricks. The fundamental component of this construction material is rectangular blocks of mycelium, which are created by combining mushrooms with agricultural waste, such as corn stalks. The breeding process takes several days, and then the bricks are air dried, obtaining a hard and light structure. In contrast to conventional construction techniques, binders or other adhesives are not required to connect the components. Instead, the bricks are manufactured in a manner that ensures a secure fit, thereby facilitating the assembly and disassembly processes. The

[11] T. Carrington, *Bioarchitecture & Carbon Negative Buildings*, master thesis, Deakin University 2015. DOI: 10.13140/RG.2.1.3818.9521 (access: 1.06.2024).

[12] M.J. Post, *Cultured meat from stem cells: Challenges and prospects*, "Meat Science" 2012, no. 92(3), pp. 297–301. DOI: 10.1016/j.meatsci.2012.04.008 (access: 25.04.2024).

[13] *In Vitro Meat Habitat* [in:] Terreform ONE, https://www.terreform.org/in-vitro-meat-habitat (access: 26.04.2024).

[14] J. Laarman, *Bone Chair (2006)* [in:] Joris Laarman, https://www.jorislaarman.com/work/bone-chair/ (access: 17.05.2024).

[15] *Ibidem*.

[16] J. Laarman, *Modern technology is "more magical than Harry Potter" says Joris Laarman*, interview by Glenn Adamson, https://www.dezeen.com/2020/06/11/joris-laarman-interview-friedman-benda-vdf/, https://youtu.be/Ov0TyW784aY (access: 14.05.2024).

resulting building material is quick to produce, with bricks "growing" for about five days; it is also cheap, as no energy is needed to make the product; durable, meaning resistant to heavy loads; as well as biodegradable – the bricks are composted for later use in local gardens.[17] This concept proposes a novel definition of domestic material, whereby the full cycle of birth, development and death occurs within the local environment.

The final *Fab Tree Hab* (Ill. 8) example illustrates processes occurring on an arboreal scale. This research project was developed in 2000 at the Massachusetts Institute of Technology by a team of scientists and designers (M. Joachim, J. Arbona and L. Greden). The main goal of the project was to build a residential unit that would have minimal impact on the natural environment, both during construction and in operation. To shape such a treehouse, a plywood scaffolding is built to accompany the tree's growth, and in the final phase, once the final arboreal form has been achieved, it is dismantled and can be used for the next construction.[18] The green structural elements of the house are formed using a weaving technique, which is identical to the production of wicker baskets. This process allows for the efficient and harmonious creation visible in nature. *Fab Tree Hab* is therefore partly a plant, and like any living organism, it adapts to changing environmental conditions.[19] Over two decades later, the concept presented here was developed further into a prototype object, *Fab Tree Hab Pavilion*. The designers examine the potential for shaping living vines to create a form that could be used in housing in the future.

5. SUMMARY

The projects mentioned in this work focus on architectural innovations, sources of which can be found in natural processes: differentiation of forms derived from genetic mutations (*Embryological House*); growing of living cells *(In Vitro Meat Habitat*); optimisation and personalisation of materials (*Bone Chair*); combining traditional construction techniques with circularity (*Hy-Fi Tower*); exploring arboreal processes (*Fab Tree Hab*). The novelty of each example is reflected in the relevant areas of innovation listed in the table (Tab. 1). Some of these areas refer to generally accepted definitions. Others, especially perception and context, are characteristic for architecture, which expands its scope. So what do individual innovations involve? The first three, namely utility, materials, and processes, are obvious to architects, so we can omit a more detailed description here. The next three, although increasingly implemented in architecture, do not originate from it: innovation in the field of production processes concerns the development of more efficient production methods that save resources, energy and time[20]; by adaptability we mean the ability of products or systems to adapt to changing economic and environmental conditions[21]; circularity focuses on products,

[17] D. Benjamin, *Reinventing the brick* [in:] E. Schwarz (ed.), *Fourth Holcim Awards*, Holcim Sustainable Construction Press, Switzerland 2014, pp. 60–65, https://d1f6o4licw9har.cloudfront.net/flip/A15/A15Book/HTML/index.html (access: 11.05.2024).

[18] *Fab Tree Hab* [in:] Wikipedia, https://en.wikipedia.org/wiki/Fab_Tree_Hab (access: 5.06.2024).

[19] S. Heinonen, *Neo-growth in future post-carbon cities*, "Journal of Futures Studies" 2013, no. 18(1), pp. 13–40, https://jfsdigital.org/wp-content/uploads/2013/10/181-A02.pdf (access: 5.06.2024).

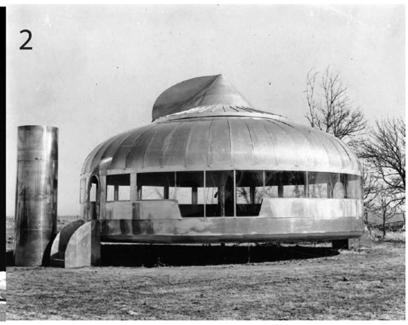
[20] L. Białoń, *op. cit.*, pp. 14–16.

[21] R. Kronenburg, *Flexible Architecture: The Cultural Impact of Responsive Building*, "Open House International" 2005, no. 30(2), pp. 59–65. DOI: 10.1108/OHI-02-2005-B0008 (access: 6.06.2024).

activities or systems that focus on reusing materials or returning them to the environment[22] – in some ways in contrast to the classical architectural paradigm expressed by durability. The last two areas of innovation are characteristic for creativity: perception – because it can transform our thinking about the existing reality; context – because it can take into account factors that were once on the margins of interest but are now crucial (for example, the context of life with all its aspects: feeling, relationships, dying, illness, treatment, etc.). We believe that the research presented here can direct architectural thought towards new ideas derived from the biological world, something that Kandinsky anticipated as early as 1918.

Table 1. Innovation areas of individual projects, own elaboration.

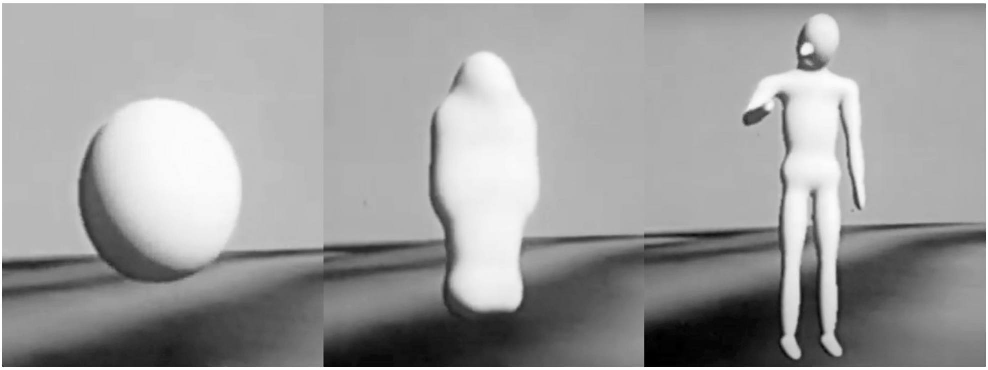
Innowation's areas / Title	Utility	Materials	Design processes	Production processes	Adaptability	Circularity	Perception	Context
Embryological House Greg Lynn	X	—	X	X	X	—	—	—
In Vitro Meat Habitat Terreform ONE	X	X	X	X	X	X	X	X
Bone Chair Jorris Laarman	X	—	X	X	X	—	—	—
Hy-Fi Tower David Benjamin	—	X	—	X	X	X	X	X
Fab Tree House Mitchel Joachim	X	X	X	—	X	X	—	X



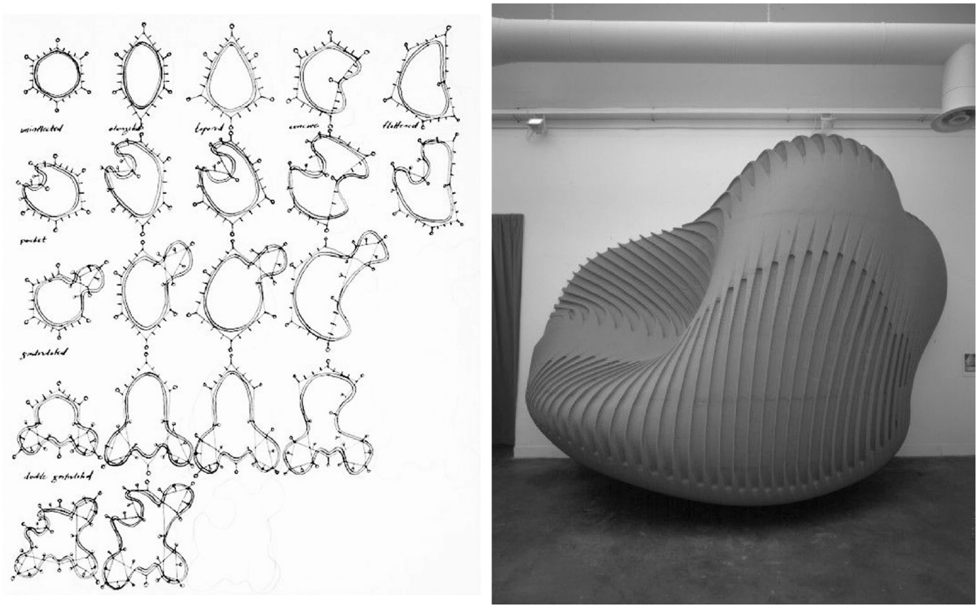
Ill. 1. *Endless House*, Friederick Kiesler, 1950–1960, source: https://pbs.twimg.com/media/EoKOd-nUVEAI1sNv?format=jpg&name=4096x4096 (access: 25.05.2024).

Ill. 2. *Dymaxion House*, Buckminster Fuller, 1940–1950, source: https://c20society.org.uk/building-of-the-month/dymaxion-house-wichita-kansas (access: 25.05.2024).

22 *Circular economy introduction. What is a circular economy?* [in:] Ellen MacArthur Foundation, 2013, https://www.ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview (access: 6.06.2024).



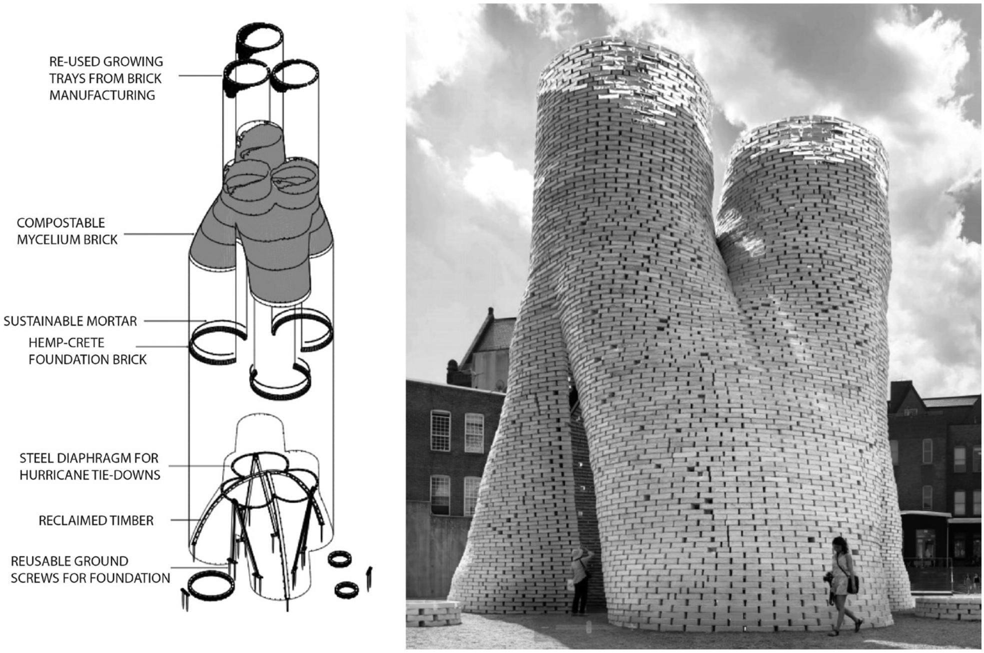
Ill. 3. Frames from James Blinn's animation tilted *The Evolution of Blobby Man*, 1982, source: https://www.youtube.com/watch?v=7vYA6sEccTY (access: 20.05.2024).



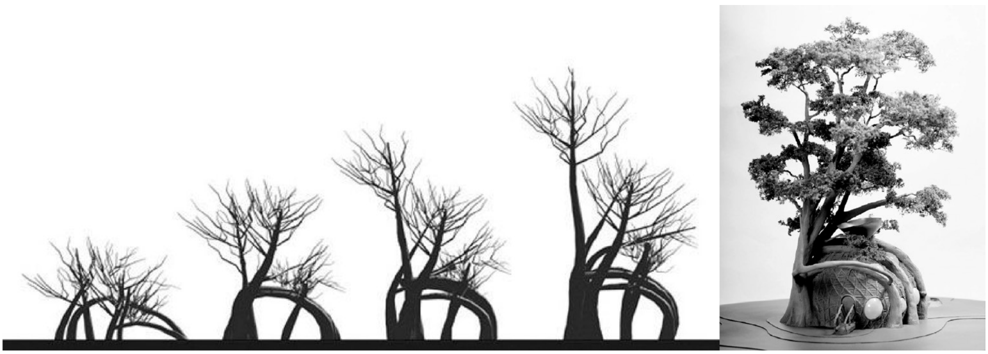
Ill. 4. *Embryological House*, Greg Lynn, 1997–2000; left: various shape configurations, source: https://future-house-genealogy.blogspot.com/p/embryological-house.html (access: 20.05.2025); right: physical model, source: https://glform.com/exhibits/biennale-2002/ (access: 20.05.2024).

Ill. 5. *In Vitro Meat Habitat*, Terreform One, 2009; left: section of a wall made of meat cells, source: https://www.terreform.org/in-vitro-meat-habitat (access: 01.06.2024); right: visualization, source: https://www.terreform.org/in-vitro-meat-habitat (access: 01.06.2024).

Ill. 6. *Bone Chair*, Joris Laarman, 2006; left: forming the model digitally, source: https://www.youtube.com/watch?v=bJ_nSSBl040 (access: 01.06.2024); right: visualization, source: https://www.sothebys.com/en/buy/auction/2019/important-design/joris-laarman-bone-chair (access: 01.06.2024).



Ill. 7. *Hy-Fi*, David Benjamin, 2014; left: axonometry with detailed structure elements, source: https://erich-mendelsohn-preis.com/de/backstein-bauten/hy-fi-der-backstein-neu-erfunden-living (access: 27.05.2024); right: prototype, source: https://erich-mendelsohn-preis.com/de/backstein-bauten/hy-fi-der-backstein-neu-erfunden-living (access: 27.05.2024).



Ill. 8. *Fab Tree Hab*, M. Joachim, J. Arbona, L. Greden, 2000; generation of form; source: A. Chin, *fab tree hab is a living graft prefab structure by terreform one* [in:] designboom, 23.08.2013, https://www.designboom.com/architecture/fab-tree-hab-is-a-living-graft-prefab-structure-by-terreform-one/ (access: 20.05.2024).

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