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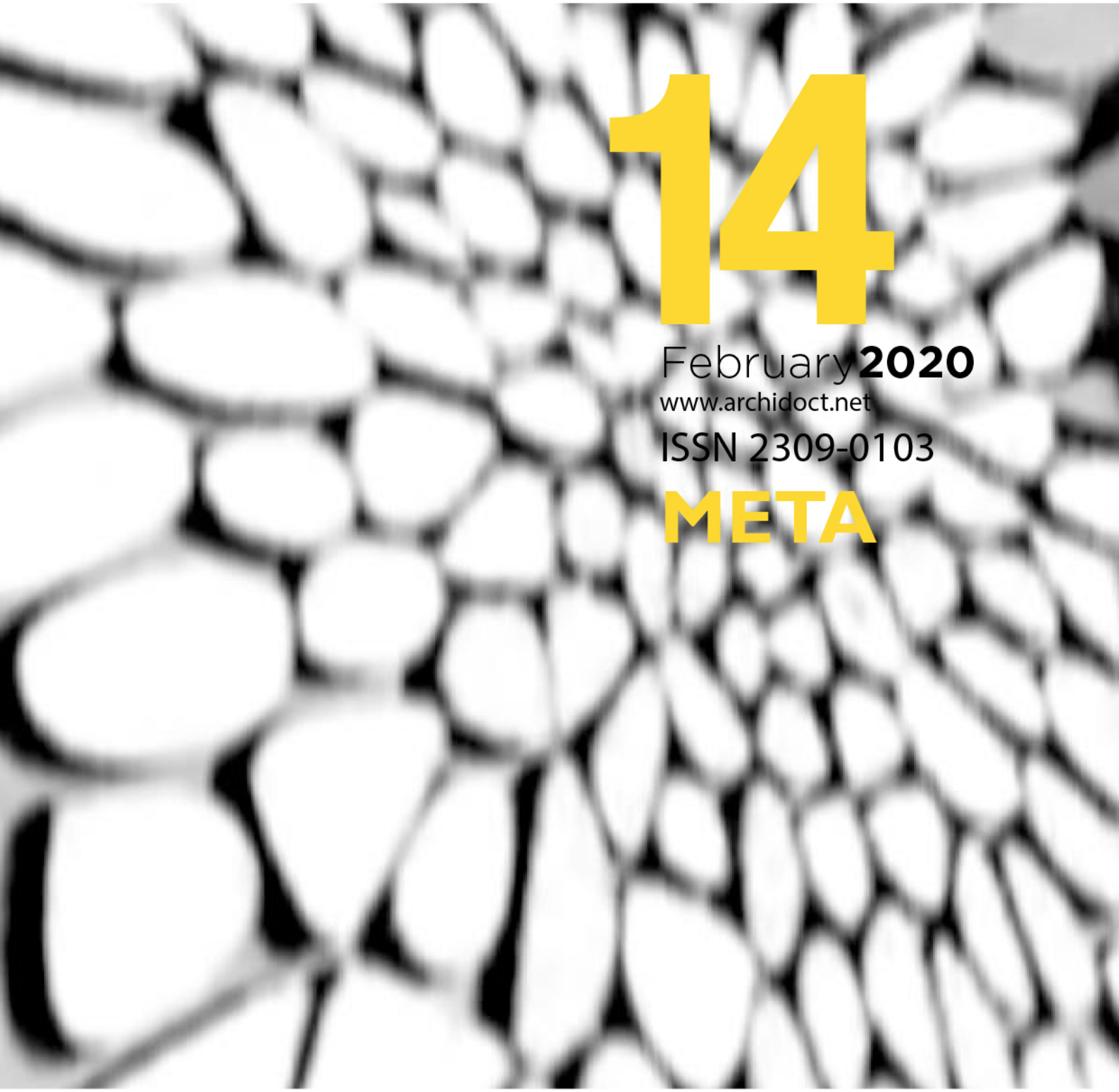

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Architecture in a Petri dish: co-programming Meta-Life in design through biointegration and synthetic biology

Selenia Marinelli // Theories and Design at DiAP (Dipartimento di Architettura e Progetto), Faculty of Architecture "Sapienza", University of Rome

Abstract

In the current era, marked by the increasing concern about antropogenic climate change and environmental problems, biotechnology and synthetic biology can offer solutions to several present and future problems concerning biodiversity. In this paper, the notion of "meta" will be discussed to investigate the concept of meta-life as grey area between the animate and the inanimate, the natural and the engineered, the born and the built, in order to demonstrate how these entangled notions could be applied also as new design strategies. The advent of synbio and bio-information as tools for architecture could in fact drastically change the way we conceive buildings as meta-living beings in ontological continuity with the biosphere.

Keywords
meta-life; synbio; biotech; bioart; ecosymbiotic architecture.

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Introduction: new models of (e)co-existence
Human, non-human and meta-natural perspectives

Disruptive developments in biotechnology, synthetic biology and computing technology have led to new possibilities to engage and manipulate life in order to demystify the mythologized conception of nature, according to which we can refer to nature only if relating to its primitive "untouched" status.

The design and construction of new biological entities dramatically challenge the common understanding of the "natural". For this reason, we can identify biotechnology as a "third nature", in which life forms are crossed and sometimes genetically manipulated to create new, synthetic and augmented ones.

The "next nature", as Van Mensvoor labels it, may also be not entirely "green", because it underlies the intersection with anthropic agents and because it leads to the creation of new synthetic meta-life forms. For this reason, many researchers in media art, science, design, biopolitics and material feminism are currently trying to disentangle some very often misunderstood and mistakenly linked notions such as naturaleness, aliveness and greenness. For instance, the recent "Un/Green" conference and exhibition at the Latvian National Museum of Art, held last july 2019, aimed to provide a cross-disciplinary platform for discussions and artistic interventions exploring the paradoxical and fetishistic employment of the concept of "green" - symbolically associated with the "natural" – often used in order to metaphorically hyper-compensate its inherent ambiguity between alleged naturalness and artificiality[1] .

With all the pros and cons, the convergence of bio-technological dimensions is increasingly strong and some applications may constitute possible and feasible scenarios of experimentation for a new ecological co-existence between different species and between man and post-natural elements.

Bioart is one of the first artistic movements assuming this convergence as key point for its investigation. In this paper we will try to upack the core of some bioartistic experimentations in order to understood how art, through bio-information, biotechnologies and interactivity, can actually work as interface to trigger a dialogue between environment, technology, human and non-human beings.

At the same time, we will focus on multiple reflections about how a meta-natural perspective could led to serious implications also in the architectural realm. The interest [2] in nature

1. See "Un/Green: Naturally Artificial Intelligences" homepage: http://ungreen.rixc.org/ and "RIXC Festival 2019, The 4th Open Fields Conference on Art-Science Research" homepage: http://festival2019.rixc.org/, last accessed 2019/09/11

2. Abondano D. (2015) "Transition towards a digital architecture: new conceptions on materiality and nature" in Moras A., Voyatzaki M. (eds) archi-DOCT vol. 2(2)/ February 2015: 29-42.

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as a process and not only as a model to reproduce, generates new opportunities about the integration of its behaviour in design. The contribution of disciplines such as biology, genetics, neuroscience, nano-bio-technologies and robotics in design and architecture is in fact relevant and it contributes to the emergence of numerous questions: how will the relationship between nature and biotechnology evolve? How will synthetic biology have repercussions also in architectural design and built environment? How can we use biotechnology in order to transform architecture itself into a biohybrid, into an example of meta-living being?

Living or semi-living? Natural or engineered? Overcoming the Cartesian dualism through bioart

Bioart represents undoubtedly one of the most significant approach to critically address concepts such as organic manipulation or meta-life.

The term was originally coined by Eduardo Kac, during his performance "Time Capsule" (figure 1) which took place in 1997: using a special needle, the Brazilian artist grafted onto his left ankle a subcutaneous microchip containing a programmed identification number, integrated with a coil and a capacitor, all hermetically sealed in a biocompatible glass capsule. With this work, the artist aimed to link art not only to figurative aspects, but mainly to the representation of the radical embodiment between a human and a technological apparatus. "Time Capsule" can be considered as halfway between an event-installation, a site-specific work (where the "site" is constituted by the intersection between the body of the artist and a remote database) and a simultaneous transmission of biological and digital informations.

Kac during his whole career tried to use the tools of biology, technology and devices to establish an inter-species dialogic communication. The intersubjective experience between biological organisms and electronic devices is in fact crucial in his early artistic research and the purpose is to use the concept of "telepresence" to build an interaction between bio-telecommunications, bio-robotics and human and non-human users (such as animals, plants and computers), in order to investigate cognitive, biological and social aspects.

His more mature works anyway started to embed also transgenic applications, proving to be able to absorb the biotechnological paradigm and to raise bioethical questions about the legitimacy of transgenic practices while used for aesthetic purposes.

Another crucial example in bioartistic experimentations is the work of Australian researchers Oron Catts and Ionat Zurr.

Back in 1996 they coined the term "semi-living" to describe compound entities generated with tissues extracted from complex organisms and kept alive by using technology. This technique of tissue culture is commonly used for biomedical purpose, but in this case is employed to create conceptual prototypes of semi-living organisms, cultivated in bioreactors. Their works undermine the very concepts of object and subject, as the cultivated biomass is actually alive thanks to a nutritional sustenance system, which prevent the non-living status.

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Figure 1.

: Eduardo Kac, "Time Capsule": view of the needle and the microchip (on the left) and view of the injection of the subcutaneous microchip in the artist's left ankle (on the right).

Source Fig.1: Eduardo Kac/Casa das Rosas, source: https://www.ekac.org/figs.html

Figure 2.

The Tissue Culture & Art Project, " Semi-living Worry Dolls", 2000

Source Fig.2: Patrick Bolger/Courtesy Science Gallery, source: "Bioart: The ethics and aesthetics of using living tissue as a medium" available at https://www.wired.co.uk/gallery/bioart-1-gallery

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In one of their most famous artworks, the "Semi-living Worry Dolls" (figure 2), Cutts and Zurr used biodegradable polymers (such as PGA and P4HB) and surgical sutures, to which living endothelial, muscular and osteoblastic cells are subsequently incorporated. They are placed inside bioreactors, that become an artificial womb where these semi-living grotesque entities can grow.

The semi-living (or meta-living) condition raises a very interesting perspective: cells and tissues, despite being able to grow and to live also outside the organism from which they are extracted, they easily lose the status of living subjects, as this quality is apparently linked to the physical body in its complexity and not also to the individual entities that constitute it. Tissue cells are in fact used in the scientific field in a utilitarian way, without assigning to them an "agency" (Bandura, 2016) or a proto-agency that should be intrinsic to their status of semi-living beings. Instead, they are compared to inert objects.

In the case of Catts and Zurr artworks, technological mediation acts as amplifier of life, by reconfiguring the physical unity in the form of an extended body. For this reason, they affirm that we need to revise the current taxonomic system of Linnaeus, since it does not take into account the most recent biotechnological progresses which problematize the usual ways of understanding life, meta-life, species and the "natural" realm.

As is often the case, these examples show how artists react to cultural and scientific progress by critically elaborating it. Bioart aims to reflect on the continuum of life through the convergence between living, synthetic, biosynthetic and artificial realms. The dissolution of the binary distinction between what can be considered as "natural" and what is culturally understood as "non-natural" is decisive in this approach. One important difference compared to other practices is that in bioart art matter is no longer painted or sculpted or enclosed into a digital dimension: it is a living biological entity. This opens to many problems about whether to base the taxonomic criterion of bioartistic "products" referring to the content (i.e. on bio-media and bio-subjects) or to the methods and means used to create bio-artworks (i.e. bio-mediums). In fact, bioart represents an unprecedented situation in which "the medium is the message" – literally; the "bio" is both instrument and subject of the communication.

In order to overcome this issue, Jens Hauser introduced the concept of "biomediality" by referring to the intervention on living organisms or biological processes, whether they are technically manipulated or not, with inter-scale operations (Hauser, 2016). Biomediality is therefore understood as a practice whose main purpose is the direct intervention on the mechanisms of the living: by transgressing a formal or symbolic representation of life, it supports a phenomenological re-materialization through the interaction between the user/environment and the living or semi-living artifacts.

Hence, the bioartistic debate does not use technology just as a tool to simulate or to reproduce life using iconic images, but it uses devices in order to break into biolog-

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ical processes and to manipulate them. It also triggers a more complex notion of ecology by implying an entanglement also with new meta-life forms created through the use of synthetic biology and biotechnology.

Bio-informed architecture: buildings as meta-living organisms

A Petri dish is a shallow transparent lidded dish that biologists use to culture cells: the potential role that biosynthesis can play in advancing architecture and urban design opens new future scenarios in which architecture itself could be produced in a Petri dish. The combination of digital design with biology and biotechnology, but also the increasing production of biomaterials from organic life forms (such as mycelium, microalgae, bacteria or protocells), can represent a gamechanger in "bio-informed" design practices. In fact, it opens to the possibility to recognize an agency also to architectural matter, thanks to the overlapping with the organic layer. Architecture can therefore act as a living system pointing to the development of a hybrid ecology.

The concept of architecture as evolving living system was pioneered by John Frazer in his publication "An Evolutionary Architecture" (1995), where he underlined the importance of using construction materials responsive to external conditions, in order to establish a mutualistic relationship between the building and the environment. As clearly stated by the cybernetician Gordon Pask in the preface of Frazer's book, this approach has nothing to do with the "often frenetic practice of copying the works of nature in architectural forms" [3] , rather it is about developing new models which are both tangible and rational, alive and in evolution. Frazer's goal is therefore clear: architecture fits into the natural construct as an artificial life form that triggers a symbiotic behavior with the environment and a metabolic balance that is proper to natural systems. Above all, the very interesting thing that emerges from the publication is the emphasis that an evolutionary architecture can be pursued not exclusively in terms of natural selection, but throught processes of self-organization and metabolism.

3. Frazer, J. (1995) An Evolutionary Architecture. Architectural Association, London, p. 7

At this point, following bioartisitc experimentations, we can assume that also as designers we need to develop a heuristic point of view to redefine the boundaries of the discipline in its interaction with the "natural", to favor complex relationships: ultimately, we need to embrace the emergence of a new collaboration between architecture and the fields of life sciences,

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biotechnology and synthetic biology. Moreover, by focusing on the creation of biohybrid artifacts, based on the coupling of organic matter or living engineered organisms with artificial supports, we can overcome the excessive formalism of biomimicry or bioinspiration.

Although recognizing a considerable value to biomimetic experiments, they in fact take nature as an inspiration and mentor (Benyus, 1997) but by keeping it ontologically separated from the artificial domain they also reinforce a Cartesian dualism. The translation of logics of natural behaviour and morphogenesis into digital realm in these cases is an abstraction, in order to outlines a bio-inspired or biomimetic design process [4].

We should rather put the emphasis on co-construction principles: we need to replace the ideal of nature as a model to be simply emulated, in order to start using it as a co-worker in design strategies. Assuming nature as an active contributor within architectural processes, we stress the fact that design outputs are results of a co-evolution.

According to Neri Oxman, we should in fact look at the technology of nature in order to open design strategies to a neomaterialist style, based on the integration between organic ("natural" or engineered) and inorganic materials.

The integration of the bio-logic leads to significantly changes in how to design the architectural envelope or in what construction and production methods to use. Furthermore, principles of growth, self-organization, self-repair or other biological principles often associated to architecture metaphorically, in this way can be applied effectively, thanks to the presence of actual living matter. In one of the recent projects with the Mediated Matter research group she founded at the MIT in Boston, Oxman used melanin as substance to represent a "universal pigment" found indiscriminately in human and also other living beings. It acts as a crucial technological system in providing protection from ultraviolet radiation, along with other important functions linked to biological survival, like mechanical protection, energy harvesting, cell growth or thermal regulation.

The installation "Totems" (figure 3) aims to investigate the possibility to intersect culture and nature by questioning this dichotomy through designers' ability to engineer melanin's expressions within and across species. The pigment used for the biological totem is in fact synthetized hybridizing an enzyme from a mushroom, called tyrosinase, and protein building block L-tyrosine, which can be extracted from bird feathers and cuttlefish. The manipulated genes for melanin production is then introduced into Escherichia coli, abling this bacterial species to express the gene itself and to change col-

4. Chang, J. (2014) "Hyper-Morphology: Experimentations with Bio-inspired Design Processes for Adaptive Spatial Re-use" in Vardouli T., Voyatzaki M. (eds) archi-DOCT vol. 2(1)/ July 2014: 50-60.

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Figure 3.

Madiated Matter Group, "Totems", 2018

Source Fig.3 Neri Oxman and The Mediated Matter Group/render by Eric de Broches des Combes, source: https://mediatedmattergroup.com/totems

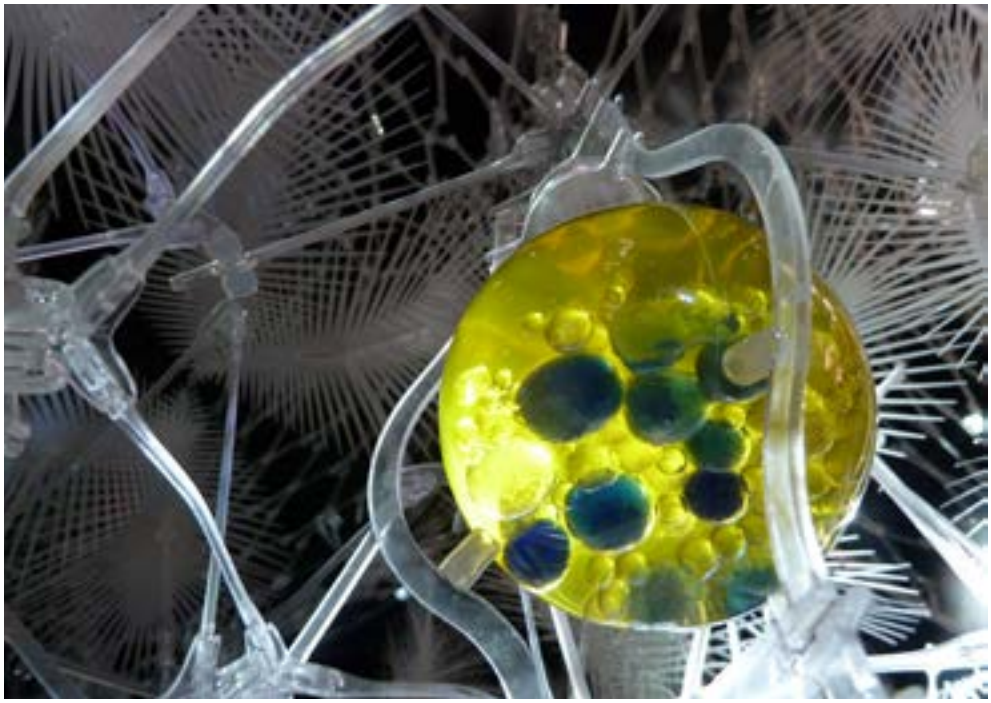

Figure 4.

Philip Beesley (with the collaboration of Rachel Armstrong), "Hylozoic Ground", 2010. Detail of the incubator flasks suspended in the installation matrix and positioned over light emitting diodes (LEDs) to capture heat and light. The flasks contain protocells (specifically modified Bütschli droplets) which are able to respond to environmental conditions.

Source Fig.4 credits: Philip Beesley, source: Armstrong, R. (2014), op. cit.

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oration in response to changes in the environment, in order to provide protection from solar radiation. Next to the design installation, the research group propose also to apply this technology in order to build an environmentally responsive melanin-infused glass structure and to obtain a biologically augmented facade.

Also Rachel Armstrong, one of the leaders of the Living Architecture Systems Group at the University of Newcastle, stands against the biological/mimetic formalism, which is based on the metaphorization. In her Manifesto against biological formalism (Armstrong, 2011) she argues that, despite the continuous parallels with the biological world, our cities continue to be built with the use of inert materials and they don't acutally follow biological principles such as metabolism, omeostasis or self-organization.

For this reason, in her research she investigates the possible use of protocells as building material, beyond a labotratory context. Protocells represent a turning point in the evolution of life-like technologies. They are prototypes of primitive cells, whose primordial nature is related to the bottom-up approach taken towards development of an artificially constructed cell. They are in fact capable of chemical self-organization, according to a spontaneous phenomenon called "emergency" and their behavior can also be engineered through the use of synthetic biology. In particular. Armstrong mainly focuses on the "meta" status these molecules demonstrate by embodying the convergence of natural and artificial systems. As she affirms, protocells "are characterized by their striking life-like qualities, which potentially have great value in design as they represent a platform that is simultaneously 'natural' in terms of its emergent spontaneity and also artificial, since they are also partly designed and deliberately constructed" [3]. Their implementation in building envelops could then transform architecture into an autonomous meta-living organism, which is able to respond to external factors thanks to a bio-active facade.

3. Armstrong, R. (2014) "Designing with Protocells: Applications of a Novel Technical Platform" in Life, 4, p. 460 doi:10.3390/life4030457.

Recently, Armstrong developped also a new prototype of "living bricks" for the Tallinn Architecture Biennale "bioTallin" in 2017. She and her research group proposed metabolically active bioreactor building blocks composed by a microbial fuel cell, an algae bioreactor and a genetically modified processor (figure5).

As many of these experiments are based on biological matter, in addition to achieving a much more promising results in terms of sustainability, they also contribute to a paradigm shift from an aesthetic point of view. The envelope, in fact, is no longer inert, it does not simply emulate natural behaviors, but it literally incorporates life becoming a meta-layer in continuous development and evolution. We prefer to define this approach as "eco-symbiotic" in order to under-

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Figure 5.
Rachel Armstrong/Newcastle University, "Living Bricks", 2017. Photo: Tonu Tunnel
Source Fig.5 credits: Tonu Tunnel, source: https://2017.tab.ee/

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lines that bio-integration of organic substances or biological organisms can bring architecture closer to establish a mutualistic symbiosis, rather than a parasitic relationship with the biosphere.

Conclusions

In the current era, marked by an increasing environmental concern, urban ecology becomes an important goal to achieve and it forces us to think about current design methods which are not ecologically aware of natural resources, nor adequately integrated into ecosystems.

The eco-symbiosis perspective applied to architecture can in fact help us to include in our future cities ecological dynamics of responsiveness and metabolism and to build positive relationships between living organisms and the abiotic forces of our cities. Moreover, by emancipating architecture and design from a mere objectification, we can start conceiving built environment as assemblage of meta-living organisms thanks to biosynthesis.

This new field of research seems very promising, even if at this stage there still few implementations at the architectural scale and designers are more focused on the production of prototypes which are generally unrelated to the more purely architectural field, as they seem to be halfway between an artistic, scientific and design project.

However, we can detect also some disadvantages related to this practice, which are mainly economical since the costs for the synthesis and maintainance of biomaterials still relevantly high. The use of biological organisms coupled with artificial materials could also generate unforeseen circumstances related to the inpredictability of living systems and this is certainly something that will need further elaboration in order to reach a certain stability at the architectural and urban scale. Another possibile implication could be the reducing of these experimentations to the umpteenth way of technical manipulation and exploitation of living systems, ecologies, and the biosphere at large.

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