BIOLUX

Growing Glowing Architecture

Graduation Thesis

ALICE BONICELLI
2016

PIET ZWART INSTITUTE
MASTER INTERIOR ARCHITECTURE AND RETAIL DESIGN

Assessors:
Max Bruinsma
Gabriel Lester
Füsun Türetken
Martine Vledder

House rules

There are no forced pathways to browse through this thesis. The reader is free to scroll through the set of cards and compose the story as he likes. From theory to aesthetic references, from scientific experiments to the final design, through photos, diagrams or written text, the reader may feel free to compose his own big picture as he wishes, like doing a puzzle or trying to untangle a rhizome.


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Abstract

What's the next step after millennia of technological evolution in **lighting systems,** from fireplaces to candles, from gas to electricity? Science tells us that in the next few years our interiors could be lit by bioluminescent, alive, unwired, matter.

This project is a **speculation on how we will illuminate the interiors of the future** and an effort to explore the light-producing properties of bioluminescent fungi outside the usual confines of scientific practice. An intricate system of tubes filled with glowing mushrooms has been designed, turning the architectural shell into a performative shell, a system in transformation, that is alive.

The tangled, rhizomatic mass is the source of light. In the bioluminescent interiors of the future, space, matter and light become one. When the interior is conceived and designed as a habitat, in which environment, users and matter coexist in a relationship of mutual exchange, how is the inhabitation affected?

Methodology

The material and spatial research threads have been developed in parallel, the outcomes and discoveries of one affecting the other.

The **material research** involved hands-on experiments in collaboration with Associate Professor Robin A. Ohm from the department of Microbiology of University of Utrecht, in an effort to understand the factors that affect the speed of growth, expansion and light emission of the mushrooms. Step by step, the mycelium of Panellus Stipticus was inoculated and grown on several mediums, tested on different materials and shapes. The results of the research determined the materials, forms and system of preservation used in the final design.

The first goal of the **spatial research** was to develop a concept for an interior as a habitat, as a living system. In order to do so, the relationship between space, man and nature in the form of the mushrooms have been explored, studying how they affect each other, through scientific literature and material experiments. Secondly, the research was directed into finding ways to integrate the concept of rhizome into interiors, both on a structural and conceptual level, speculating on strategies of infinite growth and mutualism.

A speculative project

"While combustion, electricity and nuclear power defined scientific advance in the last century, the new biology of genome research [...] will define the next. If the 20th century was the century of physics, the 21st century will be the century of biology."

(The Century of Biology, 2014)

According to A. Dunne and F. Raby (2013), speculative design *"usually take[s] the form of scenarios, often starting with a what-if question, and is intended to open up spaces of debate and discussion. Their fictional nature requires viewers to suspend their disbelief and allow their imaginations to wander [...] and wonder about how things could be."*

Interiors can be conceived as habitats, and interior design as the practice of envisioning scenarios for those habitats. An interior is a habitat insofar as it is a system, involving living matter inhabiting the space, together with inanimate matter that serves as support for life. This system is composed of people, space, energy, resources, microorganisms, materials interacting with each other. When designing an interior, we design the way humans – and non humans - will live there, their actions, relations and habits.

If interiors are habitats, then biomimetic design seems the best approach to pursue the goal of designing liveable spaces. Biomimetic design with regard to architecture is a method which consists in understanding and reproducing natural models, structures and materials in order to achieve sustainable innovation. It is one of the biggest trends nowadays due to its promise of sustainability, deriving from the assumption that if we design and build according to the way that nature does, and has done for billions of years, we will be able to develop more efficient systems, respectful of nature itself.

A speculative project

In the book *Biomimicry: innovation inspired by Nature* (1997), J. M. Benyus gives a broad overview of the innovations that could be achieved by mimicking biological processes: self-cleaning paints inspired by lotus leafs, passive cooling systems for buildings on the model of termite mounds, a type of adhesive which mimics the mechanism employed by the gecko, and so on [Fig.1].

However, sustainability is not the key factor. A biomimetic approach is relevant to the discipline of interior architecture today because it offers the potential of a wide range of innovative organisational, functional, spatial and formal models that could lead to different ways of inhabiting our interior habitats. It is not an idea of looking "back" to nature, but rather "forward", envisioning futuristic – but realistic - scenarios for our next habitats. Bio-technology is juxtaposed to digital technology, and has the scope of bringing real and alive matter within the practice of design and construction, questioning how far we have moved from a true and aware relationship with the environment. Designing with living, unpredictable, uncontrollable and maybe uncomfortable matter could make the user more aware of his experience of the space and his relationship with it.

The goal of this thesis is to develop an spatial lighting system [Fig.2] through the use of bioluminescent mycelium as main material feature. Through a cross-disciplinary approach, combining interior design and biology, the thesis will investigate the consequences of the application of biological matter on an interior space, questioning the functional, aesthetic and philosophical value and the relation with inanimate matter. The design will try to find a feasible solution that will allow the mushrooms to grow and illuminate the space, while contributing to reinforcing the structure.

Research questions:

- What type of system derives from the use of living luminescent matter as main construction material?

- Will it be possible, in the future, to provide an interior with light by using bioluminescent mycelium as alternative to artificial illumination?

- How does the life cycle of a building change when living matter is applied?

- What type of space derives from the application of alive, growing, luminous matter?

- What are the benefits and drawbacks of inhabiting a growing and living space?

- How does the relationship between architecture, environment and users change?

Figure 1.

Sawa, M. (2013). Algaerium

Figure 2.

Philips, (2011). Biolight.

Growing architecture. Buildings as organs

"These [future] systems won't be machines but will be a different kind of technological platform, which we can call an 'assemblage', with completely different outcomes and impacts on the environment to those we associate with the industrial age."

(Armstrong, R. 2013)

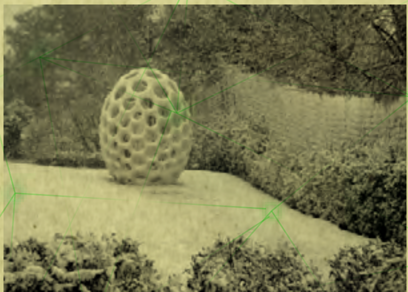

Figure 3. Estévez, A. (2008). Barcelona Biodigital Pavilion

The integration between architecture and biology is already reality, as proven by the increasing popularity of bio-digital parametric design such as the works by Arquitectura Genética, which take formal inspiration from structures present in nature. Models such as the veins of a leaf, drops of water, the DNA of certain proteins are studied and then reproduced by algorithms that allow the digital design of highly complex, and supposedly highly performative structures, through so-called morphogenetic design processes [fig. 3].

In reality, a design approach which is inspired by nature brings with itself far more complex consequences which go beyond the mere imitation of form and function, but imply the **embedding of biological matter,** processes and systems. As William Meyers puts it in his *Biodesign*, a collection of architecture, designs, speculative and art project experimenting with biology, *"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."* (Meyer, 2012).

Understanding this, means to become familiar with an important concept, which is that we are no longer asked to build buildings, but to grow buildings, and that the spaces we live in are to be considered as alive as we are.

Growing architecture. Buildings as organs

The theories elaborated by scientist-designer Rachel Armstrong are quite precise about the theoretical and practical shift that comes from implementing biological, live, matter into architecture. Whether this matter is soil, as in her project Persephone for inhabitation of out-of-Earth space, [Fig.4] or protocell droplets, with which she envisions what she calls "self-repairing architecture", the fundamental idea is the same: our world is lively, unpredictable, in constant transformation. Buildings should be conceived as "extended physiologies", designed for instability in a world alien to the concept of eternity [Fig.5].

"Culturally, in the modern Western world, we use machines as our technological platform. Machines come from a very particular way of understanding the world. They have a unique ontology that is born from a very particular set of ideas. Most notably machines assume reality is made of objects, which can be defined geometrically and hierarchically linked. It also assumes that the world is at effective equilibrium where matter is passive, so machines need external energy for their functional object hierarchies to do useful work. Nature doesn't work like that. […] These [future] systems won't be machines but will be a different kind of technological platform, which we can call an 'assemblage', with completely different outcomes and impacts on the environment to those we associate with the industrial age." (Armstrong, R. 2013)

Natural processes involve a high level of interdependence, being part of a system. The type of space that this thesis envisions is closer to being an organ, rather than a machine. It tries to escape the Modernist model of "machine à habiter", leaving the paradigm of industrial functionalism behind,, getting closer to the model of natural habitats, where environment, users, matter and energy affect each other and their interaction warrants the functioning of the system, in a constant, mutual, exchange.

Co-existence becomes the paradigm, in a sort of symbiotic relationship between the microorganisms and humans, which might depend on each other in a delicate balance. The project wants to explore whether this could alter our sense of self and our conception of environments in and around us.

Figure 4.

Watson, P, Morris, J. (n.a.). Visualisation of starship Pershephone.

Figure 5.

Beesley, P. (2010). Hylzoic Ground.

Permanence and impermanence within the architectural envelope

"Building envelops may be thought about in terms both of the interior realms of the building and their capacity to address the forces of the larger exterior environment. From part to whole, from local to global, from micro to macro, everything is connected and connectable, in constant, harmonious flux and unfixed in time or space."

(Mazzoleni, I. 2013)

When approaching the study of the luminous mycelium, in the form of the brightest known species which is Panellus Stipticus, it was soon found out that the mycelium, being a rhizome, has the striking property of being an excellent binder, due to its thread-like structure and its growth in every possible direction, reinforcing the substrate it grows on. Consequently, the concept of the project is necessarily entangled with the subject of architectural envelops [Fig.6]. The system of illumination envisioned by this project will not take the form of lamps or light appliances, but it will be embedded as part of the architectural envelop. A supportive structure will be designed, that encloses and determines an interior, and allows the growth of the mycelium within the structure itself, assuring the necessary environmental conditions for the mushrooms to live and shine. The architectural shell, or as we could better call it, in this case, the performative shell, becomes, more than ever, and intermediary between the surrounding environment, the built space, and the user, entering the discourse of the relationship and balance between life and death, stability and transformation, fixation and growth.

Permanence and impermanence within the architectural envelope

Figure 6. CRC Press, (2014).

Dealing with biological matter, implies the necessity of making a distinction, for the sake of feasibility and consistency, between when the concept of rhizome and growth are applied metaphorically and literally, and to define the balance between human design and natural growth. The designed shell will be then composed by two main features: a fixed structure, designed and programmed to perform certain functions, such as the one of containing the mycelium, preserving it from noxious elements of the environment, and assuring light to pass through; this part refers visually to the concept of rhizome and provides the conditions for the mushrooms to act as a rhizome, but it is indeed stable, inanimate. The mycelium itself, which will "fill" the structure, is the impermanent, unpredictable, alive and growing part of the system, which colonises the dead matter. The mycelium couldn't survive without its rhizomatic container, and the container would lose purpose if emptied of its rhizomatic micro-inhabitants.

Deleuze's rhizomatic space

Smooth space is filled by events or haecceities, far more than by formed and perceived things. It is a space of affects, more than one of properties. It is haptic rather than optical perception. [...] It is an intensive rather than extensive space, one of distances, not of measures and properties. Intense Spatium instead of Extensio. A Body without Organs instead of an organism and organization.

(Deleuze, Guattari, 1987)

As any other fungus, *Panellus Stipticus* is characterised by two principal stages of growth: a first phase in which it has the form of mycelium, a sort of soft, fluffy, hairy layer that spreads across everything that can be "eaten" by the fungus, and a subsequent phase in which fruit bodies, given the right environmental conditions, grow out of the mycelium, which is what we normally identify as "mushrooms". A mycelium is a particularly interesting object, from an aesthetic and structural point of view, as it presents a rhizomatic structure.

A rhizome is, first of all, a concept borrowed from botanical sciences that describes the growth and propagation of certain types of roots; secondly, the concept was studied and elaborated by philosophers Deleuze and Guattari in the 70's and 80's, leading to the formulation of the philosophical, social, and economical model of the rhizome, as opposed to the tree-model and it was one of the most influencing ideas of Postmodernism. A rhizome, in nature, is a type of root which is typical of species like fungi, lichens, and grass. It differs from a tree root, because it looks as a tangled and intricate mass of filaments with no origin and no end and no hierarchy in their growth. Moreover, it develops in the form of a network, in which every point can be reached by any other point, through a series of random and endless connections.

Deleuze's rhizomatic space

The space created by a rhizome is defined as "smooth space" by Deleuze and Guattari: contrary to "striated space", which is hierarchical and has fixed pathways, smooth space is continuous, with no discernible pathways and gateways. [Fig.7,8.] Wandering through it, literally or metaphorically, means to undertake a "nomadic" journey through disorganised matter (Deleuze, G., Guattari, F., 1987). By observing the growth of the rhizome in form of mycelium, we can notice a planar movement of growth, as the hyphae (the "filaments" of which is composed the fungal mycelium) tend to expand covering a radial pattern, which, however, seems to resist chronology and organisation as it responds to the concentration of nutrients to direct its growth, favouring a "nomadic system of [...] propagation" (Abouzakhar, 2015)

By analysing the concept of rhizome as it is discussed by Deleuze and Guattari in A Thousand Plateaus (1987), involving the idea of nomadic movement, smooth space and disorganised matter, this thesis aims to find a way to express such a spatial concept through the use of bioluminescent mycelium.

Figure 7.

Saraceno, T. (2010) 14 Billions (Working Title),

Figure 8.

Isreali Pavilion, (2016). Life Object: Merging Biology and Architecture.

Blobitecture

The idea of looking at nature for inspiration has always existed in architecture, going back to the Greeks who sought perfection in natural laws, passing from the Art Nouveau movement in the XIX century which made natural and organic forms its distinctive sign, till more recent times with a trend called “Blobitecture”, which actually claims philosophical roots in the concept of rhizome. Blob architecture is a term coined by Greg Lynn in the 1990s, and usually indicates buildings which have an organic, amoeba-shaped, form (Curl, J. S., 2006) generated through computer aided design [Fig.9]. The fascination with these shapes seems to derive from the will of understanding and imitating the logic behind natural morphogenetic processes; they can be seen as “rhizomatic” - on a metaphorical level rather than on a literal one, which would be unrealistic – as they try to escape the hierarchical model of traditional orthogonal floor plans and facades. However, in their claim of being organic and natural, these architectures can never do without the help of digital system for generating the shapes.

This project, dealing with the idea of rhizome and trying to propose a model of interior that escapes the Modernist box, cannot leave aside references to Blobitecture. By aiming to design an intricate and tangled structure, the result will be closer to a cloud of interconnected elements arranged in fluid and irregular volumes, turning the interior’s usually flat surfaces into 3D networks.

Figure 9.

Panton, V. (1970). Phantasy Landscape Visiona II.

Panellus Stipticus

"While we may admire a mushroom growing out from the soil or a bracket fungus growing out from a log, it is the out-of-sight (and often forgotten) mycelium that is the essential part of the organism. The mycelium […] is not a static object. It grows and may die [...] producing different growth forms or structures, depending on circumstances."

(Australian National Botanic Gardens and Australian National Herbarium, 2012)

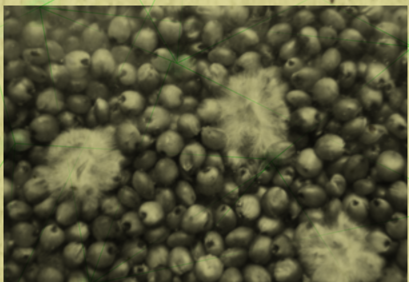

Figure 10. Bonicelli, A. (2016). Early days of Panellus Stipticus II.

Panellus Stipticus emits luminous radiation within the green wavelength, around 520-530 nm thanks to a chemical reaction involving the production of an enzyme, luciferase, which is responsible for the luminous radiation. The intensity of the radiation emitted depends on several environmental factors and on the stage of growth of the fungus. Typically, the mycelium alone [Fig.10] (the initial stage of growth, from 1 to 6 weeks after inoculation) is way less bright than the fruit bodies, which may sprout after 2-4 months. As tested through experiments in the lab of the department of Molecular Biology of University of Utrecht, the mushrooms develop only with the right factors, such as light, oxygen, level of ph, temperature. The medium influences the brightness as well: a medium which is richer in nutrients results in a visible increment of the amount of light emitted. Panellus is also characterised by a vegetative form of reproduction, meaning that the birth of new strains does not occur sexually. This means, that the generation of new cultures of mushrooms can be created artificially just by cutting pieces of existing tissue and placing them somewhere else, generating a perfect clone.

The current light yield is very weak: it is not enough to read the words of a book, for example [Fig.11,12]. At least for now. In fact, due to the popularity that fungi in general have been acquiring in recent years, for the potential of producing light sustainably and off the grid, researchers are positive in claiming that in the next 5-10 years, through genetic crossing of species, *mushrooms might shed light in our houses (Ohm, R., 2016).*

Figure 11.

Ohm, R. A. (2015). Panellus Stipticus

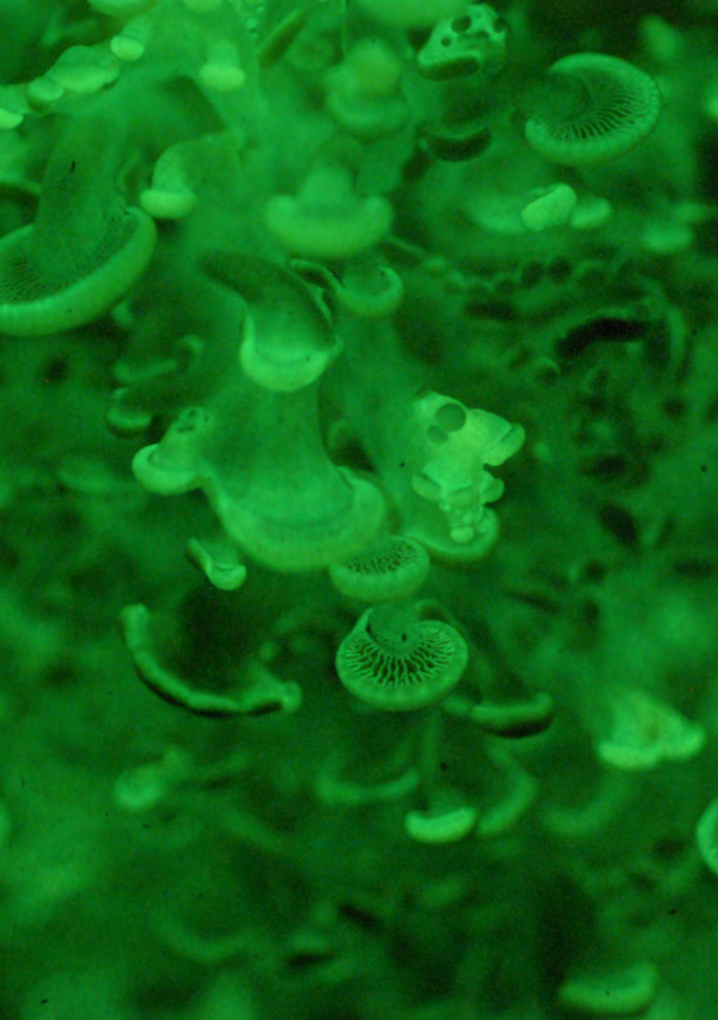

Figure 12.
Ohm, R. A. (2015). Panellus Stipticus

Green light to cure sleep disorders

Sleep disorders have become more and more frequent in recent years, adding to the ones due to seasonal change. In fact, the ever increasing number of electronic devices with their blue light- emitting screens have been proved to be able to affect the production of melatonin in human organisms, and, therefore, displace people's circadian rhythm. Moreover, the higher number of people travelling long distances, with consequent jet lag disorders, and people working night shifts, have increased the amount of individuals suffering from sleep disorder. (Sack, RL et al, 2007).

There have been several experiments based on exposing people with altered circadian rhythms to a certain amount of green light, for a certain amount of time, and measuring how quickly their biological systems were able to retrieve the original day-light cycles due to the benefits of green wavelength (Division of sleep medicine Harvard Medical School, 2010). Exposing people to green dim light apparently affects the production and suppression of melatonin and would help to reset the internal clock (ibid.)

Therefore, why not exploit the natural property of bioluminescent mushrooms of emitting constant dim light on the green wavelength (around 520-530 nm)? The mutual relationship between space, matter, and humans, would be shifting from passive use to active and reciprocal collaboration, making us aware we are not just responsible for the growth of the space we live in, but the interior we inhabit is actually doing us some good.

Enhancing light emission: what's the best substrate?

This first phase of the project dealt with hands-on experiments with Panellus Stipticus in order to investigate the best conditions for the material to grow and to make light. The research was conducted in collaboration with Associate Professor Robin A. Ohm from the department of Molecular Biology of University of Utrecht, and touched upon several subjects such as which variety of Panellus was best to be grown, the phases of growth, the techniques of inoculation, and the best environmental conditions to keep the organisms alive and prevent them from being infected by other bacteria.

Once it was clear how to "give birth" to the first cultures of Panellus [Fig.14,15], the second phase of the project focused on understanding what is the best medium onto which to grow the mushrooms. It soon turned out that the mycelium, being alive and needing food, would not work on not-biological material. The mushrooms need a substrate that they can easily break down to get energy: specifically, they particularly like lignin therefore any ligneous material and any derivate would be suitable, such as wood chips, saw dust, cork, wood itself, paper, etc., when mixed with the right amount of water. Moreover, adding soaked sorghum grains to the composite revealed to be a solution appreciated by the mushrooms, which would grow much faster and denser, and give better results with regard to bioluminescence.

* Lignin is a class of complex organic polymers normally found in wood and bark.

**A plant belonging to the grass family, with leaves and grains similar to corn. It is often used as food for birds and it particularly indicated to develop culture of mushrooms due to its high nutrient values.

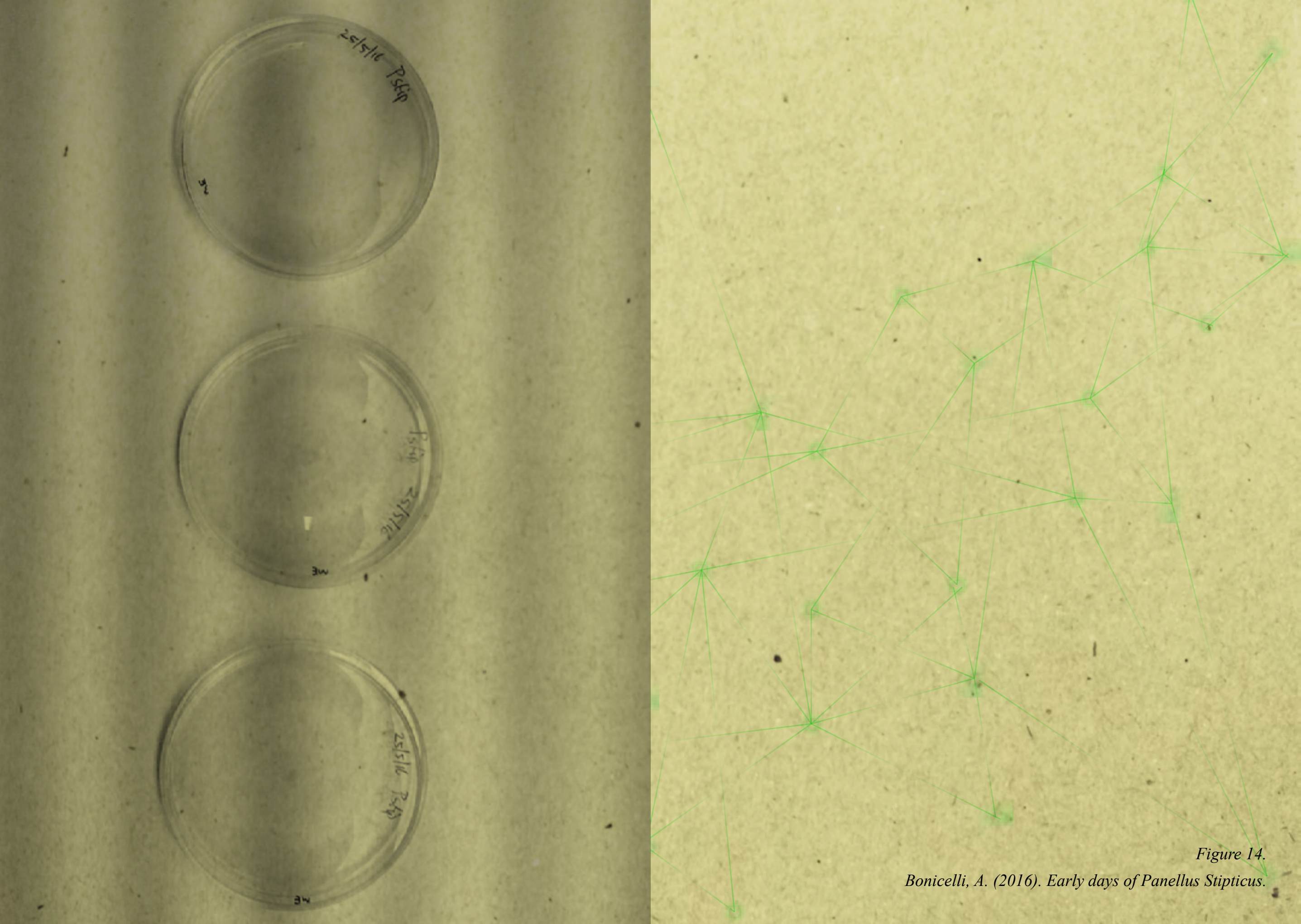

Figure 14.

Bonicelli, A. (2016). Early days of Panellus Stipticus.

Figure 14.

Bonicelli, A. (2016). Inoculating Panellus Stipticus

Sealing and risk of infection

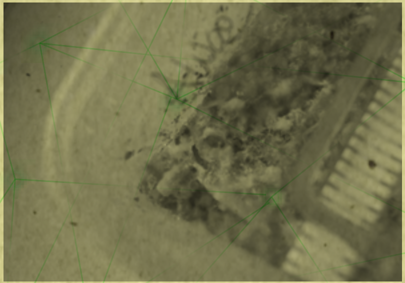

Figure 13. Bonicelli, A. (2016). Growing Panellus Stipticus II.

Mycelium and mushrooms are highly sensitive to the surrounding environment and highly subjective to infections. It is enough that some bacteria present in the air get in contact with the existing Panellus, for it to be contaminated. Therefore, whatever form the surface will take, it needs to be a sealed system, with microscopic openings to let oxygen molecules through, but no microorganisms [Fig.13].

The primary goal of the system is making light. Therefore, the outer shell, that carries the function of sealing and filtering, needs to be transparent or translucent, or porous enough to let the light pass through. Such observations led to the choice of glass or transparent plastic equipped with tiny openings, such as holes, provided with some sort of filtering system, [Fig.16,17] as main material feature into which growing the mycelium, after tests with other see-through materials such as metal meshes.

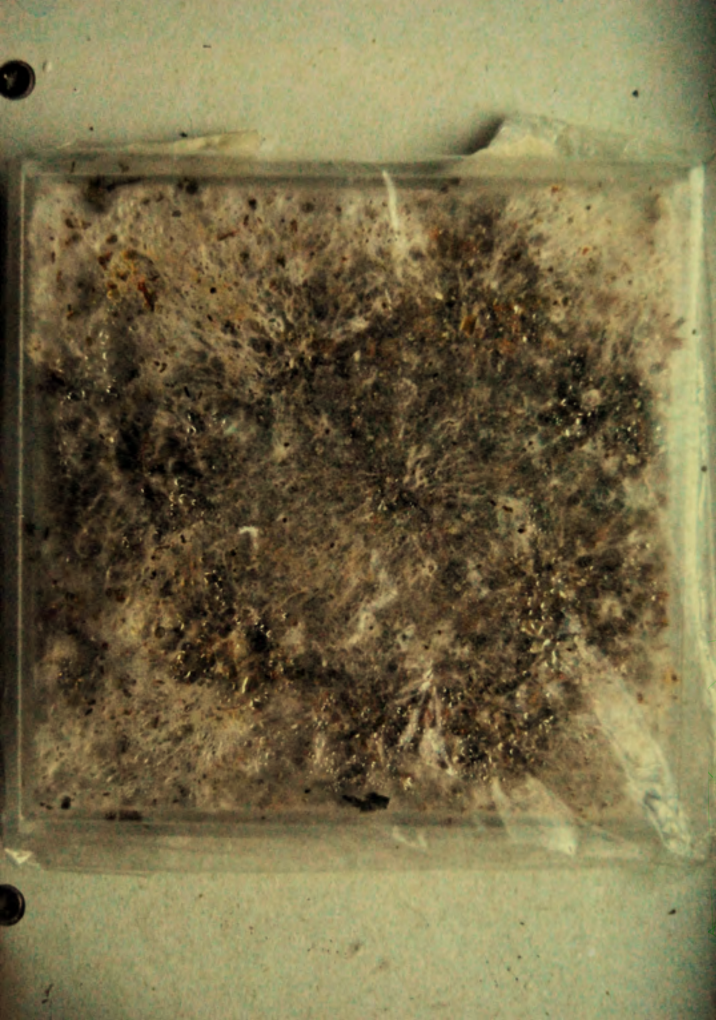

Figure 16.

Bonicelli, A. (2016). Sealing and Transparency I.

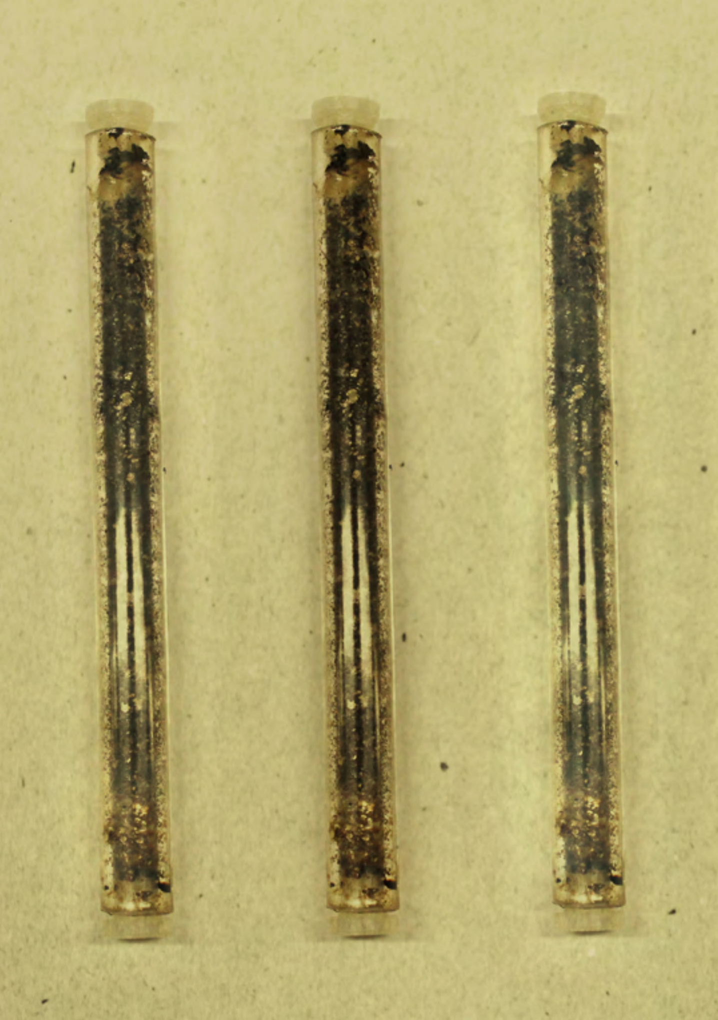

Figure 17.

Bonicelli, A. (2016). Sealing and Transparency II.

Directing the growth

Is there any specific shape or conformation that somehow affects the growth of the mushrooms? Is it possible to guide the growth according to the designer's desires?

It was soon found out that yes, the growth and spread of the mushrooms can be partially guided. For example, the mushrooms wouldn't grow where there are no nutrients. Therefore, it is possible to draw "paths", where we place nutrients in the specific areas we want to be filled, freeing up the possibilities of using the mycelium in a decorative and functional way [Fig.18]. For example, if we want more light in some specific area, we would need to put ligneous material just in the area desired; or we could play with effects of softer/brighter light according to the distribution of nutrients in space.

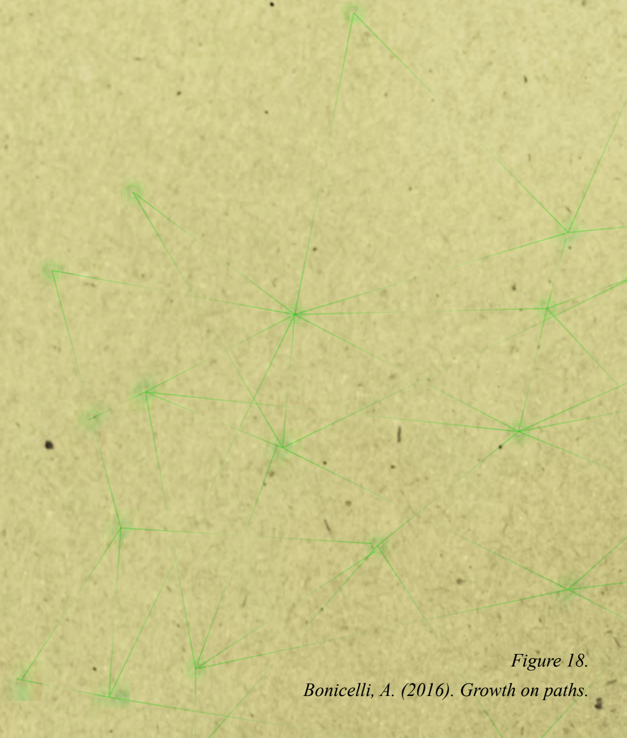

Figure 18.

Bonicelli, A. (2016). Growth on paths.

Interiors as habitats

" [...] a house is not a box. After thousands of years of lessons from nature, [...] why should a home be a box?"

(Estèvez, A. T., 2007).

Knowing that we have to share our dwelling with living creatures, how does this affect the current notion that we have of space and architecture and inhabitation? Could we be on the edge of a new era, where interiors are given the possibility of escaping the model of the modernist box towards alternative scenarios? To start thinking about architecture as a living organism, means to question the results and the process of design itself. Design becomes co-design, a collaboration between the human genius and natural laws, in a process which is the complete opposite to the obedient digital geometries that we are used to work with. It involves a factor of high unpredictability, to be taken into consideration for the end result, which leads to architecture in endless transformation. Also, it means that when designing, the material becomes the starting point: the form derives from the laws of the live system, and not the other way around, and it means to come to terms with natural laws, that may be manipulated but only to a certain extent.

A crucial part of the design is the investigation of technical solutions that allow an inanimate structure to be colonised by living matter and to establish what is going to be fixed and stable and what will be the impermanent features. We will not talk about growing envelops, but rather about material light growing within the envelope.

Interiors as habitats

By creating hybrids of inanimate and animate structures and materials, the project wants to challenge the modernist idea of clear boundaries between the built and natural worlds, showing how hybrid systems, based on mutual relations, can benefit and help preserve one another.

Mushrooms as main construction matter need certain specific environmental conditions to be alive and make light; the environment itself might benefit from the presence of the mushrooms, that have a consistent role into breaking down compounds and contribute to processes of biodegradation; human users benefit as well from the presence of a biological source of light, which helps to re-establish the circadian rhythm. All these relations contributed to shaping the notion of the interior as habitat.

Rhizomatic structures

"[…] a rhizome is an interlocking web. It is a conjunction of dynamic relations – producing bulbs here and there, interweaving with great complexity, reaching out in its continuing growth. It represents the principle of dynamic, varied pluralism that absorbs the hierarchical structure of a tree."

(Genosko, G.,2001).

The subject of architectural envelopes is also relevant as it involves the notion of connectivity. Connectivity is a parameter typical of natural systems, and it refers as well to interdependence and transformation. In the case of this project, connectivity and transformation regard both the micro scale, as the cellular structure of the material is a rhizome, and the macro scale, as the mycelium could be the binding tissue across the whole structure. The shell that delimits the interior space should be reinvented in both form and functions. In this project, the architectural shell will be freed from its orthogonal limits, to be explored on the basis of the idea of rhizome, which leads to the concepts of networked and interconnected structures. [Fig.20].

In order to allow the light to grow freely in every direction and cover every inch of the space, so to provide an extensive illumination, it was necessary to design a system of interconnected elements, as in a rhizome. Every part must be reached and colonised by the mushrooms, and every part can be replaced by new elements, if necessary, without compromising the functioning of the system. The solution was sought in art and engineering examples of network structures, either made of wires, tubes, or threads. The works of Tomas Saraceno were an inspiration, such as *14 billion* (Working title) (2010), or the study of tensegrity structures [Fig.19].

Rhizomatic structures

Studied consistently and tested by Buckminster Fuller and Kenneth Snelson among others, tensegrity is a structural principle based on the use of isolated components in compression inside a net of continuous tension, in such a way that the compressed members (usually bars or struts) do not touch each other and the pre-stressed tensioned members (usually cables or tendons) delineate the system spatially (Gómez-Jáuregui, 2010). The fascination with tensegrity structures comes from the fact that they are modular structures, usually based on a prism-composition of elements, which can be rearranged and scaled up for a variety of situations: they are structures, but they are nevertheless used to design objects, sculptures, or even architecture such as bridges and towers and domes. I wanted to reproduce this idea of scalability and potentially infinite expansion [Fig.22].

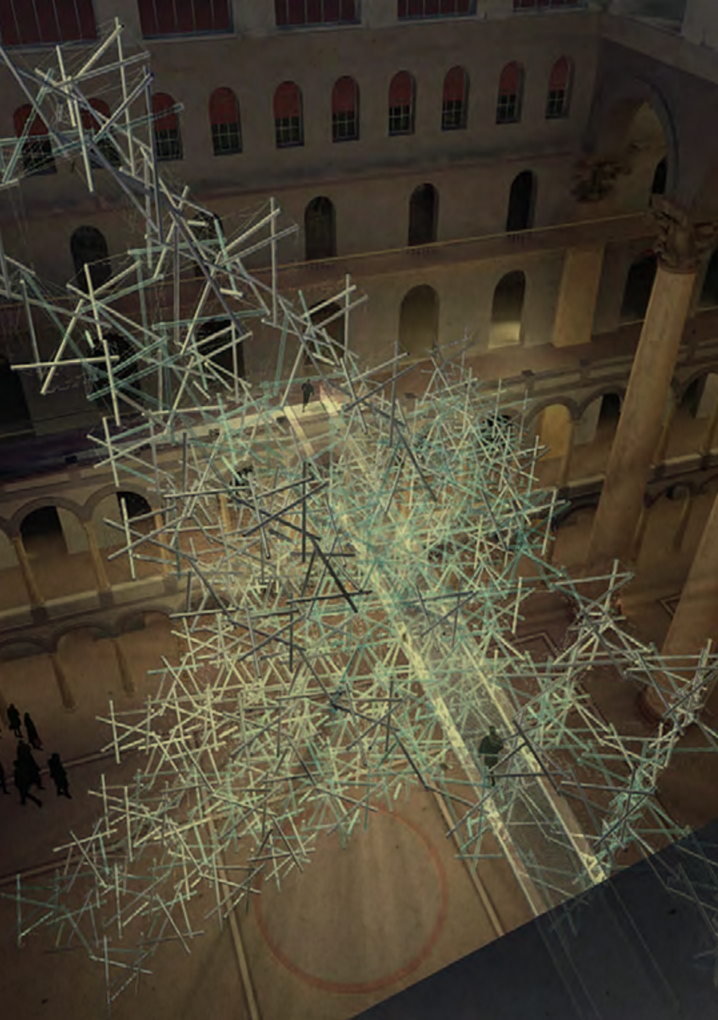

Figure 19.

Wilkinson Eyre, (n.d.). Tensegrity Bridge.

Figure 20.
EDHV, (2011). Christmas Chemistry.

Design of a bioluminescent system of illumination for future interiors

Electricity-based lighting systems are infrastructures which are added onto, or into, the architectural shell. In the case of bio-based lighting system, the infrastructure is thought to become integral to the actual performative shell that encloses the space. In the bioluminescent future interiors, space and light become one [Fig.23,24].

Why is that a desirable condition? As a practical consideration, it means that the illumination of what is inside the architecture becomes independent. Humans, starting from prehistoric times, had to bring external devices into the space they were living in, to overcome the lack of light in enclosed spaces: first, they found out how to make fire; then candles came, followed by gas illumination, ending up with electricity and light bulbs. Those devices have always been additional, separated from the interior space, or wired to the walls. Making the actual architectural envelop able to produce light, causes the interior to become self-sufficient, at least from the lighting point of view.

In order to do so, it is necessary to provide a pre-existing structure for the mushrooms to grow on, and this is where the designer comes in. The structure also has to provide enough flexibility of use, so that for the user can adjust the level of light emitted. Whereas the structure is pre-determined, the process of growth will be quite unpredictable. Even though it is possible to relatively enhance the brightness and growth by playing with factors such as nutrients and shapes, we cannot completely control what is by its nature a live matter. We will not be able to control the speed or direction of growth, nor the chances of infections and potential death. This means that the bioluminescent interior of the future will be articulated through systems in transformation; the role of the designer is to set the framework and the parameters for the transformation to happen.

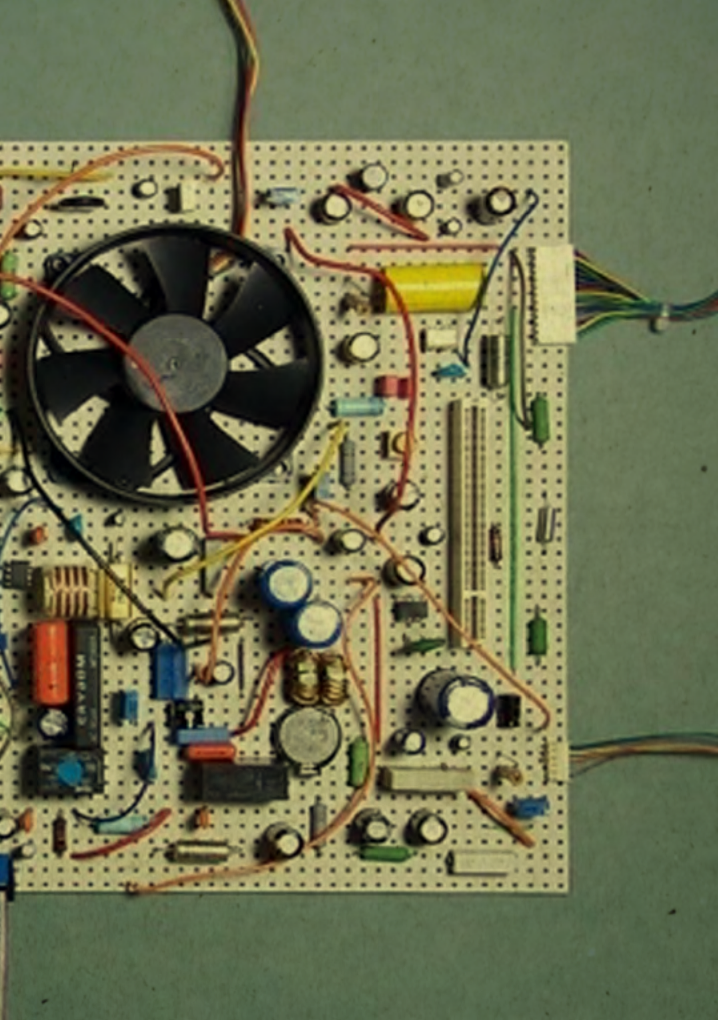

Figure 23.
Anon. (n.a.) Electric Circuit

Figure 24.

Bonicelli, A. (2016). Biological Circuit

Strategies for infinite growth: capillary structures

Electricity-based lighting systems as we know them are made of a network of cables and light bulbs or light tubes. Bio-based lighting systems might look like a network of transparent pipes and customised joints filled with growing luminous mushrooms.

The more scalable and flexible the system is, the better, as it means it can be applied to a higher variety of spaces and situations. That is why a defined general shape is not an added value, but rather having a system of construction which is replicable is what matters. By designing an easy and flexible way to assemble the parts, one can think of flexible and scalable systems that anyone could use and apply to their own situations. From here comes the decision of working with tubes and joints. It seemed a simple yet working solution.

The system was thought as a combination of rigid and more flexible transparent tubes held together by custom-designed joints, resembling the idea of blood vessels, or of bones and muscles [Fig.22]. Every 3D printed joint has nine entries that could be occupied by a maximum of 9 tubes, leading to an area of 90 tubes every ten joints. Not every entry needs to be occupied by one tube: if the user desires a weaker illumination, she/he could decrease the number of tubes per joints, leading to a lesser concentration of light [Fig.26].

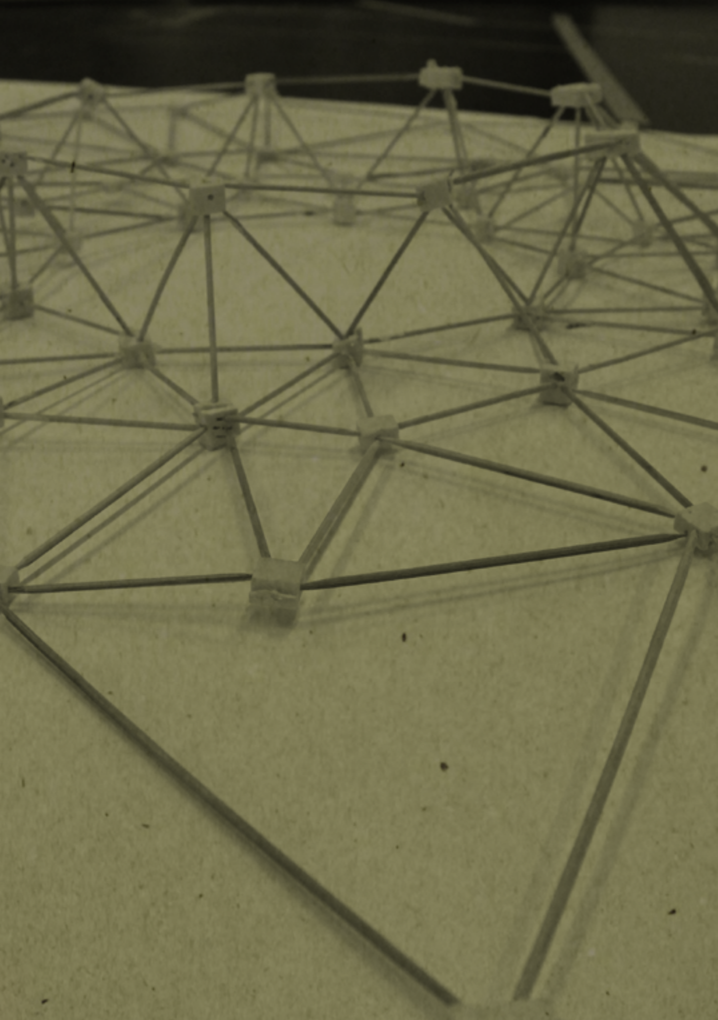

Figure 21.

Bonicelli, A. (2016. Model I.

Figure 22.

Bonicelli, A. (2016). Model II.

Customisation

How can the user set the light according to his needs, given that the mushrooms cannot be switched on and off easily? One solution is given by flexible tubes, that could be "unrolled" to reach further points of the spaces, or "rolled up" to concentrate more light in some specific spot. Or, if one needs more light, he can swap the position of the tubes, bringing the more mature cultures, which are brightest, where more light is needed, and newly born and almost dead cultures where darkness is needed [Fig.25].

The system designed this way would normally produce only diffuse illumination. What about spot illumination? The mushrooms are not very suitable for that purpose, but the joints could be an answer. The joints have an inside volume which is bigger than one single tube, and is concentrated in one spot. If the joint is filled with medium, and the mushrooms grow in it, it should produce more light, in a more concentrated spot. Of course this couldn't substitute a proper spot light, but it felt like the closest available option.

How to design a system that can be used in the highest variety of situations? Maybe someone could want to illuminate just the top of the bed for night-time reading. Someone else would want to cover up a wall of their living room, someone else would want to enclose a room so to create a relaxing and "healing" space for insomnia. Someone might want to build the whole house with such a system. The system needs to be as universal as possible, and through the system of joints and tubes, other parts can be indefinitely attached so to have the system grow in every direction the user wants, and to cover up a surface as big as he desires.

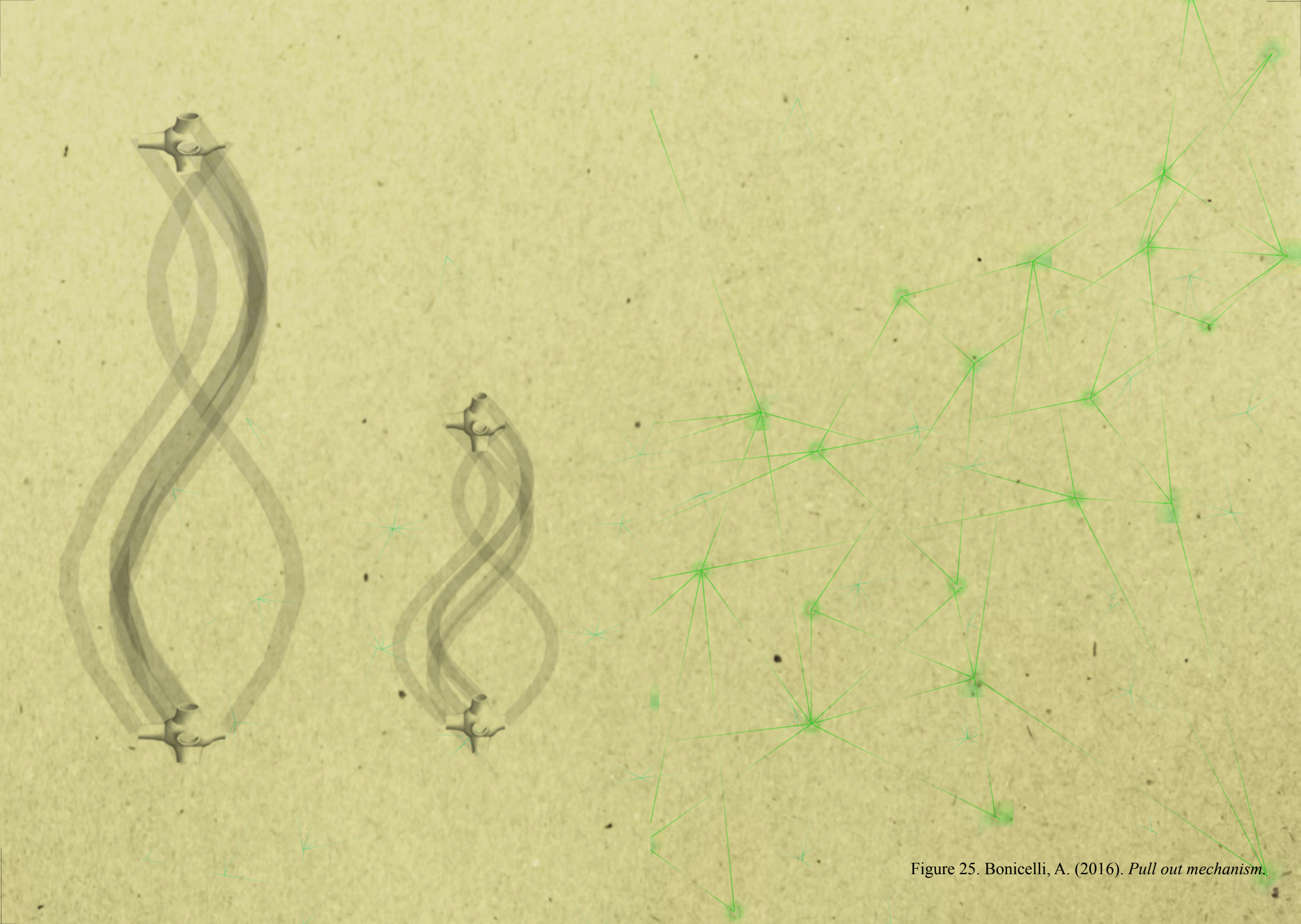

Figure 25. Bonicelli, A. (2016). *Pull out mechanism.*

Figure 26. Bonicelli, A. (2016). *Joint*.

Nomadic inhabitation

The life cycle of Panellus leads to inevitable questions of durability and efficiency. In fact, even though the mushrooms are proven to be able to survive for several months, at some point they will eventually die. Moreover, during its life cycle, Panellus Stipticus encounters different stages of development, with accordingly different degrees of luminance.

This leads to the hypothesis of nomadic inhabitation of bioluminescent interiors, as the light literally moves along the patterns of nutrients. For example, the part of the structure which is at the top of its brightness could be planned to host activities which require the highest degree of luminance, of for more intensive light therapy. When the brightness of that part of the system will eventually decrease, then new activities could be hosted there which require less light. The next interior could be an alive assemblage of environments growing out of each other where people can perform activities according to the stage of life and the consequent level of illumination of the system [Fig.27,28]. This is not necessarily the most desirable scenario, but it is a possible consequence that might derive from the use of alive matter into construction.

When the whole system dies, what are the options? Either the tubes are gradually replaced, so to keep the system in a loop of birth-growth-death, or, the system will eventually dry off. It could then be brought back to nature, or it could be left as a self-sustaining impermeable structure hardened in a fixed shape by the dried mycelium. The structure could then still be inhabited, without the benefit of light-making, or left as a monument of impermanence.

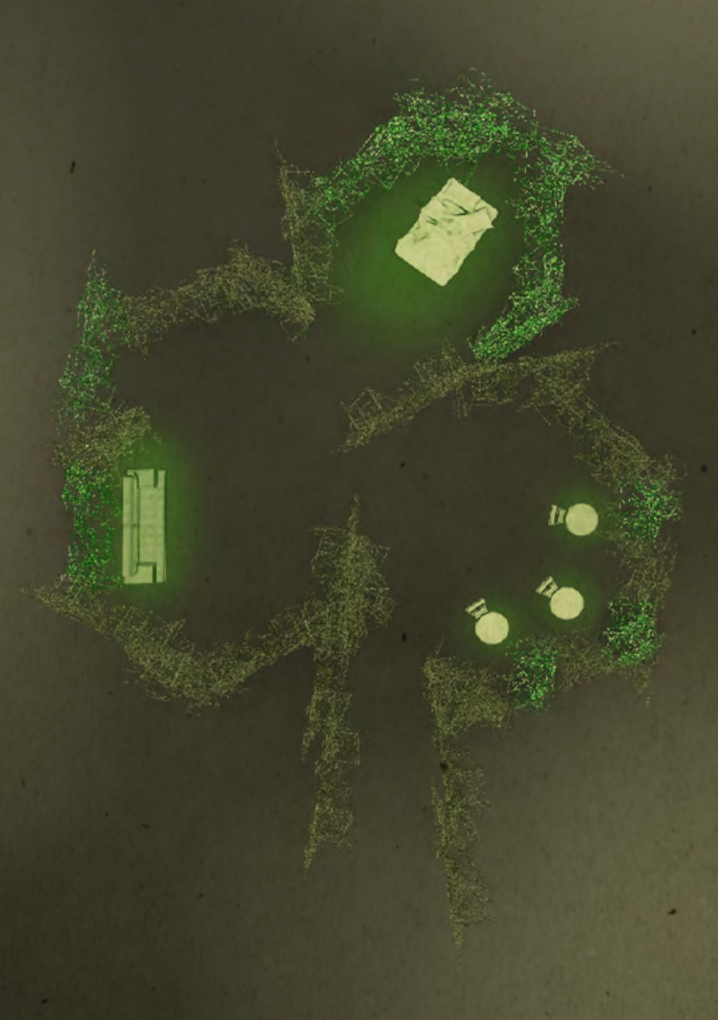

Figure 27.

Bonicelli, A. (2016). Nomadic Inhabitation A.

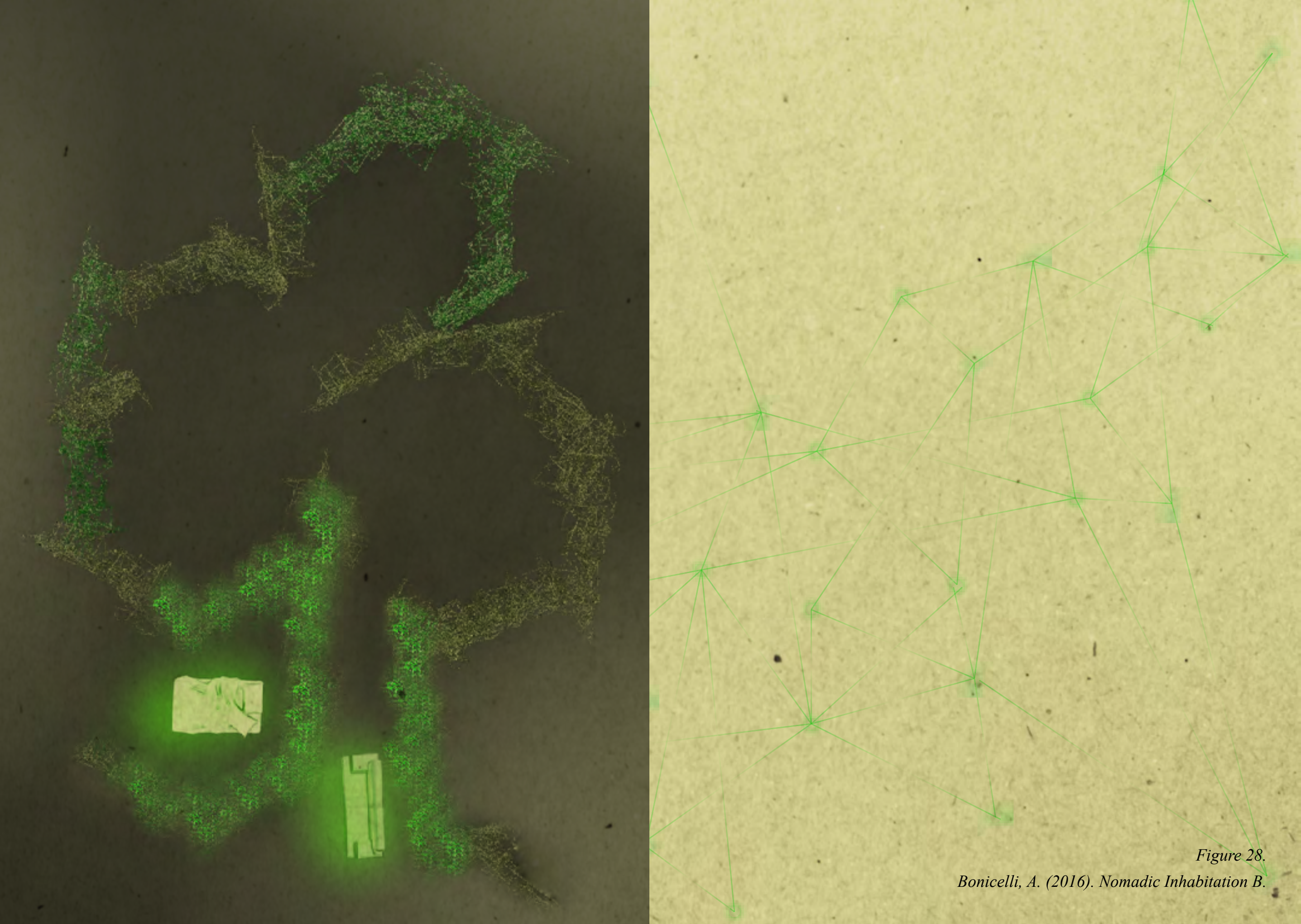

Figure 28.

Bonicelli, A. (2016). Nomadic Inhabitation B.

Changing the rhythm

The project is a comment on the consequences that come from changing construction and inhabitation paradigms by introducing live microorganisms to perform functions such as lighting, which we normally associate to machines that respond immediately to our commands. It implies a conceptual shift from using the interior to collaborating in an ecosystem of mutual relations with the microorganisms. By creating hybrid bio-technological architectural envelops, we have to accept shifts in the pace and the rhythm we are used to live in our interiors. The living lighting matter takes weeks, if not months, to fully propagate across the surfaces and to develop bright fruit bodies. The presence and intensity of light itself is not granted, as the cultures might get infected and never get to shine. Does that imply a shift in the rhythm according to which we arrange our daily activities?

This fact determined the distribution of cultures inside the designed system. The brightest "branches" are positioned in a frontal position, to be quickly visible to the user, while the less developed cultures are placed at the back, as background illumination that more slowly fades into the darkness. Also, the brightest elements should be placed next to spots of interest, such as edges, and other potentially dangerous elements, to better navigate in the dark.

The question of comfort

Not everyone could be comfortable with the idea of sharing his/her own dwelling with alive creatures, especially if these look like moulds. Most likely, most people tend to associate moulds and fungi with something unpleasant, such as diseases, rotting, infections. In fact, this project also questions usual conceptions towards this type of microorganisms and suggests an alternative way to look at them, as helpful in assuring liveable conditions, providing a basic human necessity such as the need of light. The system needs to be designed so as to guarantee the functioning of the mushrooms, but also to make the user comfortable in being surrounded by them. That is why the aesthetic qualities of the system are relevant, to guarantee a pleasant look and experience of the system, and sealing becomes beneficial to both parts.

Limitations and next frontiers

Growing Glowing Architecture is meant to be a speculative project. Through the design of the system, I am suggesting one possible solution, what interiors could look like in the future, not what they necessarily should. I am trying to envision a possible future and one of the goals of this design is also to raise questions of feasibility, comfort and functionality of such a system – in the context of what our living spaces could be, if the ongoing scientific research on bioluminescent species will be proven successful [Fig.29].

The design is one possible scenario, that tries to envision the issues that could rise from the application of living matter as source of light, ranging from functionality, speed of fruition, psychological and health side effects, practicality, duration. Some of the solutions proposed are more developed, others are less, due to the lack of scientific experimentation for certain applications (e.g., the problem of spot light or the necessity of having an extra fixed structure to support and protect the growth). From this point of view, the project doesn't aim to provide a clear answer to the question "how could we live in future bioluminescent interiors?", but rather to engage into the debate whether this is a desirable future or not.

Conclusively, my project can be understood as outlook on a future habitat that we could be living in sooner than we might expect.

Figure 29.

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