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INTEGRATION OF BIO METHODOLOGIES IN ARCHITECTURAL DESIGN: A NEOPLASMIC SPATIAL EXPERIMENT(1)

BİYO-METODOLOJİLERİN MİMARİ TASARIMA ENTEGRASYONU: BİR NEOPLAZMİK MEKAN DENEYİ

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Öz: Doğa, ilk çağlardan bu yana insanlık için büyük bir ilham kaynağı olmuştur ve doğayı taklit mimarlıkta da karşımıza çıkar. Doğayı anlamak için kullandığımız biyoloji ve teknolojideki ilerlemeler mimarlık başta olmak üzere diğer alanları da etkiler. Özellikle genetik alanındaki gelişmeler; dijital tasarım teknolojisiyle birlikte, mimarlığın yaratım süreçleriyle ilgili tasarımcılara yeni olanaklar sunar. **Amaç:** Bu çalışma, mevcut biyolojik materyali keşfetmeyi ve dinamik yapılarını gözlemleyerek mimari tasarımla paralelliğini araştırır. Doğal ve yapay arasındaki sınırların bulanıklaştırılması ve mimarlığın daha geniş bir ekoloji içinde düşünülmesi amaçlanmaktadır. **Yöntem:** Makalede, biyodijital mimarlık kavramları ele alınmıştır. Biyoloji ve mimarlık etkileşimi dijital ortamda bilgisayar üzerinden okunmuştur. Bunun ışığında, mikro ölçekte küf mantarı üzerinde yapılan çalışma dijital ortamda bir tasarım yöntemi olarak sunulmuştur. **Bulgular:** Mantarlarla yapılan deneyler sonucunda, gözlemlenen yapı dijital ortama aktarılmış ve biyolojiyi mimari tasarıma dahil etmek için metodolojik bir veri olarak kullanılmıştır. **Tartışma:** Mimarlar olarak doğayı temel aldığımız tasarım yöntemleri analojinin ötesine geçmeli ve bunun için biyoloji ve mimarlığın ortak çalışmasına yönelmeliyiz. Sonuç: Araştırma kapsamında ulaşılan sonuç, gelecekte biyolojik malzemelerle hibritleştirilmiş yapıların yaygınlaşacağıdır. Canlı ve yapay arasındaki bağlantı, yarı yaşayan mimarinin temelini oluşturur. İleri teknolojiler ile tasarım malzemesi benzersiz niteliklere sahip olacak ve yapıların kendi kendine büyüyüp inşa edilmesi mümkün olabilecektir.

Anahtar Kelimeler: Biyo-Dijital Mimarlık, Zamana Dayalı Mimarlık, Postparametrik, Kendini Üreten Sistemler, Yarı Yaşayan Mimari, Hibrit Mekânlar

Abstract: Since the early ages, nature has been an inspiration for humanity, and the imitation of nature also appears in architecture. Biology and technology are used to understand nature and with the developments in these fields; architecture is greatly affected along with others. Advances in genetics along with digital design technology, offer new possibilities to designers for the creation process in architecture. **Aim:** This study explores parallelism with architectural design by exploring existing biological material and observing its dynamic structures. It is aimed to blur the boundaries between the natural and the artificial, and to think of architecture in a wider ecology. **Method:** In this article, the concepts of bio-digital architecture were discussed. The interaction between biology and architecture was read by experimentation on fungi. **Findings:** As a result, the structure that's been observed was transferred to the digital environment and used as methodological data to incorporate biology into architectural design. Discussion: As architects, the design methods we base on nature should go beyond analogy, and for this, we need to turn to the joint work of biology and architecture. **Conclusion:** The conclusion reached within the scope of the research is that hybridized structures with biological materials will become widespread in the future. The connection between the living and the artificial lays the groundwork for semi-living architecture. With advanced technologies, the design material would have unique qualities and it may be possible for the structures to grow and build themselves.

Keywords: Bio-Digital Architecture, Time-Based Architecture, Post-Parametric, Generative Systems, Semi-Living Architecture, Hybrid Spaces

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INTRODUCTION

The understanding of architectural space is changing constantly and the biggest inspiration for that change is the connection between biology and architecture. Our culture is moving away from classical mechanisms and reductionism, and a more fluid spatial understanding dominates design with today's technologies. Physics as a model has dominated classical understanding for about five hundred years, however, it's now replaced by the biological model (Kwinter, 1993: 212-213).

Nature can be a model for design[1] as Benyus (2007) stated in her Biomimicry Theory and it's also the key model in this research. A design strategy model is established by reading the change of nature against physical forces. This change is measured with time, which is a parameter in this study. We need to use the knowledge of biology not to learn about nature, but to learn from nature by integrating with the ecosystem.

An important quality that nature has is its capacity to become endless and its evolutionary characteristics. With the evolution in mind, buildings won't be static and won't have an end form. These growing buildings would include user interaction which leads to open-ended systems. It is possible to produce advanced materials in architecture by giving biological components or organisms new functions other than their original roles in their structures or ecosystems. Biology and the principles of nature exemplify architecture in a variety of ways and the distinction between natural and artificial is becoming increasingly blurred. The biological approach to architecture places the traditional static model in a more advanced system of dynamic organizations (Lynn, 1999:10-11).

As a result of bio-architecture, the tools and methodologies we use are changing, our aesthetic intention is changing, and even the terminology we use is changing. Our perception of the world also becomes biological as we are exposed to biological themes by the media. We are particularly familiar with biological terminology and use concepts such as "genetic engineering, cloning, transgenics, pharmaceutical design, plastic surgery, and bioterrorism" in the common language of society. When traditional language is not enough to describe this new environment, we have to use biological and medical terms. By using concepts such as "morphogenesis, and homeostasis", we are starting to look at architecture from a different perspective through language (Cruz, 2008:6-15). As a result of the biologicalization of our world and the increase in interdisciplinary working methodologies, new definitions in architecture are

1 https://www.youtube.com/watch?v=2oVZsZu1lmI

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sought and a design understanding that leads to hybrid technologies, new materials, and living forms emerges (Cruz, 2008:6-15).

As the human species, we are part of a wide ecosystem and communication network. This communication network is not limited to the creatures we see around us, it also includes the microbiological realm that we do not see, and the ecosystem consisting of connections is damaged by the environment we design (Cruz, 2008: 6-15). In this period when we are further away from nature with industrialization, we can change this situation by turning to nature and learning from it to turn the life span of the planet in our favor. As architects, we must go beyond analogy to the design methods on which we are based on nature, and for this, we must turn to the joint work of biology and architecture.

The integration between biology and design creates new spatial possibilities and design; it evolves towards programming and controlling the growth, evolution, and mutation of biological structures. The physical environment transforms by feeding on the principles of biology, and in this process, the perception of space also changes. The effort to strike a balance between biology, the environment, and architecture is important when it is wanted to design, plan, or understand sustainable environments. This work uses exploring and manipulating existing biological material as a design method. It explores parallelism with architectural design by observing the self-organizing processes and dynamic structures of living organisms.

Valuable lessons can be learned about symbiotic relationships and sustainable systems as a result of research. As a form generation and organizational structure resource or as a conceptual catalyst for biomimetics[2], the scope of work at the biology-architecture interface is extremely important. This research output can be beneficial for creating a colony on other planets like Mars and so on. Bio-architecture includes light materials, oxygen-generating structures, and using genetically modified cells as building blocks. This design method would be possible by using a method that includes collaborations between architecture, biology, and technology and bio-architecture is the first step towards such a future.

AIM

This study, it is aimed to use the knowledge obtained from the experiment as a new method in architecture and to be a bio-method at the intersection of biology-architecture. It is requested that the theoretical and practical information obtained as a result of the study fill the bio-digital architectural design gap in the performance-based architectural design

2 https://www.ted.com/talks/janine_benyus_biomimicry_in_action

literature and future researchers will benefit from the experimental data. The objective is to contribute to the bio- digital architecture literature and be a continuation of Cruz's work in the literature.

CONTENT and RESEARCH METHOD

The integration between biology and design creates new spatial possibilities, and in this study, the effects of developments in the field of biology on architectural design will be explained and discussed over possible new paradigms that may arise in architecture. First, it is desired to examine the biological structure and to understand the technology of this structure, which has been formed over a million years. The codes in the self-formation methodology of systems in nature will be analyzed and transferred as a method to the spatial design.

With the integration and the emergence of hybrid methods, the line between building and nature is blurring. These methods consist of crossbreeding organic and artificial life. Where the building ends and where nature starts will be hard to differentiate thanks to fractal structures. In hybrid structures, just like living structures, there is natural growth. These organisms have unlimited growth potential; however, the control should still be on the designer. Therefore, programming these organisms using genetic engineering is needed. A semi-living architecture can be achieved by trial and error and through experimentation.

In this study, the analysis will be carried out in two stages. The first stage covers the developments in architecture in parallel with the advances in biology. Architectural theories related to biology will be listed and two approaches in bio-digital architecture will be discussed. In the second stage, the communication, colonization, and organization forms of microorganisms with each other will be examined through experimental architectural studies. Space alternatives that can be formed at the macro scale (architecture scale) will be presented with the inferences obtained from experimental studies on microbes. In this study, the growth and colonization of molds in non-manipulated environments will be observed. The observation made will be photographed and transferred to digital media as data. Biology and architecture interaction will be read on the computer in a digital environment. Biological material will be transferred to architecture with digital techniques.

The research is limited to the examination of Biodigital Architectural theories which inspired the experimentation part of the study. The experiments were held at room temperature with the limited features of the digital microscope (Dino-Lite AM4515T8 Edge

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Digital USB Microscope) that was used. Only 800x magnification was achieved with the microscope. The formation process of the molds took 2 weeks and the digital process was completed in a week. Since hybrid technologies and the usage of organic matter in design are new concepts and the current technology is not qualified for such designs to be realized yet, the research was held digitally for further study.

DISCOVERY of BIO-ARCHITECTURE

Mankind has been inspired by nature for hundreds of years. The most notable early inspirations can be found in Leonardo da Vinci's works, and his studies on birds. After the 17th and 18th centuries, which focused on systematic biology, classification and comparative study of living things, the 19th century witnessed the birth of evolution and cell theory, the beginning of modern embryology, the inclination to plant anatomy, and the discovery of heredity laws. The concept of the proportion of the human body gave the architectural design a natural ecological view, followed by acknowledging the influence of natural sciences on architecture, and finally led to an evolution of biological formation up to biomimetics (Diagram 1).

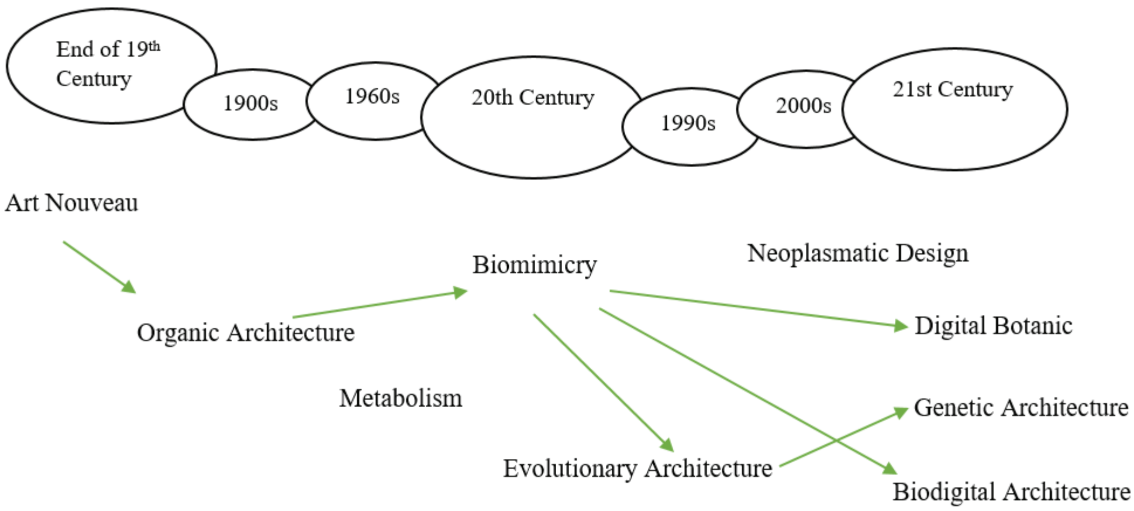

Diagram 1. The Chronology of Bio-Architectural Theories

Biology and the principles of nature exemplify architecture in a variety of ways. The application of anthropomorphic principles to buildings creates the link between nature

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and architecture. Günther Feuerstein defines this approach as «biomorphic architecture». Le Corbusier and his followers claimed that buildings are living organisms and suggested that rules in living systems can guide the building's organization. Many people, including Buckminster Füller, Frei Otto, and Eero Saarinen, examined biological occurrences in terms of morphological circumstances and applied biological concepts to design new structural and formal systems.

According to Selçuk and Sorguç (2007:451-459), inspiration from nature in the design-production process in architecture is done in two ways. The first one is, using analogy to transfer the natural form to the structure. The second way is observing the natural form and its emergence and using experimental data to transfer this knowledge into architectural form. From the first examples of the history of architecture until the first half of the 20th century, it is possible to say that usually the first method was adopted by designers. Inspirations from nature range from birdhouse-built huts to complex structures.

In 1969, Charles Jencks in his book *Architecture 2000: Predictions and Methods*, made a prediction implying that in 1990 biology will become an important metaphor in the years and a source for the most prominent architectural movements. Multidimensional developments in the relationship between biology and architecture show that where this subject is used as a metaphor or analogy in architecture and where it is used as a source of inspiration should be well analyzed (Frazer, 1995:11-15). The developments in biology and genetics found their reflections in architecture as well as in design in a short time (Diagram 2). The argument that the architectural structure is a living organism, which some architects frequently include in their future discourse, is the clearest indicator of this reflection.

The relationship between biological concepts and architectural theories can be viewed in two ways. The first is morphogenesis, evolution, and mutation, which are biological concepts that fall into the field of genetic architecture and evolutionary architecture. Concepts of Genetic Architecture such as "morphogenesis" or "morpho-ecology" refer to the creation process of form, so the key to the concept of morphogenesis is form finding. The concepts of evolution and mutation represent the structure that changes over time. Evolution is considered progressive, which also triggers adaptation. An organism that can adapt to its environment can evolve to adapt to changing conditions. On the other hand, mutation refers to an error in the organism's code but still, it's a concept that makes diversity possible. (Frazer, 1995: 11-15).

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The concept of symbiosis, which inspired bio-digital architecture and was also adopted by Metabolists, is about the coexistence of two different living species. We can see the reflection of this on architecture in hybrid structures. Although the building blocks of architecture are not "living", we can talk about a symbiotic relationship between architectural elements hybridized with organic matter. Self-organization, which is another concept of bio-digital architecture, represents the self-construction of the biological structure.

Genetic Architecture/ Evolutionary Architecture	Biodigital Architecture
• Morphogenesis • Evolution • Mutation	• Symbiosis • Self-organization • Adaptation

Diagram 2. Biological Concepts and Their Relationship with Architecture Theories

The argument that the architectural structure is a living organism, which some architects frequently include in their future discourse, is one of the clearest indications that architecture is influenced by biology. Eugene Tsui in his book *Evolutionary Architecture* states that to be inspired by living creatures means taking their adaptive and living skills as examples. Raudovski expresses the architectural interpretation of morphogenesis with three basic elements. According to him, the architectural design tries to solve similar problems solved in nature, takes living things as an example, uses adaptation development concepts and systems in nature, and uses learning by modeling development and adaptations in a virtual environment.

TWO APPROACHES in BIO-ARCHITECTURE: DIGITAL and ORGANIC

From the 1990s to the present, architects such as John Frazer, Eugene Tsui, and Greg Lynn are taking the movement and form in nature as an example and using them in their design philosophy. Inventing new architectural systems that are natural; considering architecture to be a part of nature are new ways to think about design. A parallel strategy encourages interactions between architecture, biology, and industry, enabling designers to join industrial and manufacturing development to produce new biomaterials. Bio-design allows the discovery of new, hybrid typologies beyond imitating nature in terms of melting the

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boundaries between the natural and the built environment. In bio-design, living organisms or ecosystems are included in the design as essential components. Material alternatives in which bacteria are integrated into concrete construction systems are being discussed to extend the service life of concrete construction elements and not consume more energy and resources due to ecological reasons. By creating hybrids from living and non-living materials, designers are pushing the clear boundaries drawn between the built environment and nature.

There are two types of space that genetic architecture can occur: digital space and physical space (Diagram 3). Digital space contains artificial DNA therefore it creates a mechanical structure. Physical space contains real DNA therefore it creates organic structures. Living materials are being used in hybrid-space experiments.

Artificial "DNA" (software) that's been used for the formation of bio-digital structures is processed digitally with a computer. The resulting morphology can be observed by simulation. Here the building material is inanimate (artificial) and there is robotized production of digitally designed architecture. In this approach, digital design and manufacturing are seen as a genetic process.

With the application of natural software (DNA) and real genetic processes with living elements to architecture, the integration of living structures into architectural structures is realized, and thus hybrid structures are formed. It is used to obtain living elements, building materials, and useful living spaces for architecture. It becomes possible to transform it into "directed" building materials and livable spaces through its special genetic designs, thus producing 100% ecological, recyclable and sustainable architecture that provides maximum energy savings throughout the construction process which does not require manual labor. Estevez (2005) implies the importance of genetic code over digital code. This approach, however, is debatable in terms of technology and ethics.

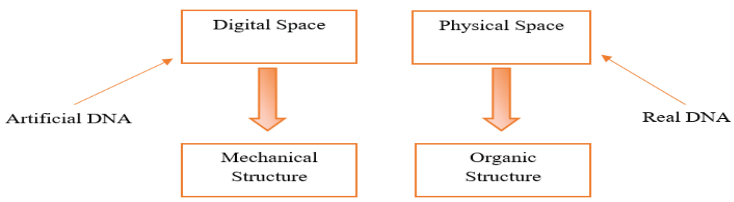

Diagram 3. Digital Space vs. Physical Space

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To create biological information by using computer technologies in the field of biology, new biological research areas such as bioinformatics and computational biology have been developed (Diagram 4). Understanding molecular structures and biological processes have made important improvements in the field of biology amongst other disciplines. Being able to prepare DNA, RNA, and protein sequence models provided architects to gain access to biological models of natural processes. John Frazer and Greg Lynn are top architects who include natural metaphors in their designs, make metaphorical connections with models for explaining biological systems, and aim to develop a new tool that will constitute the design process itself.

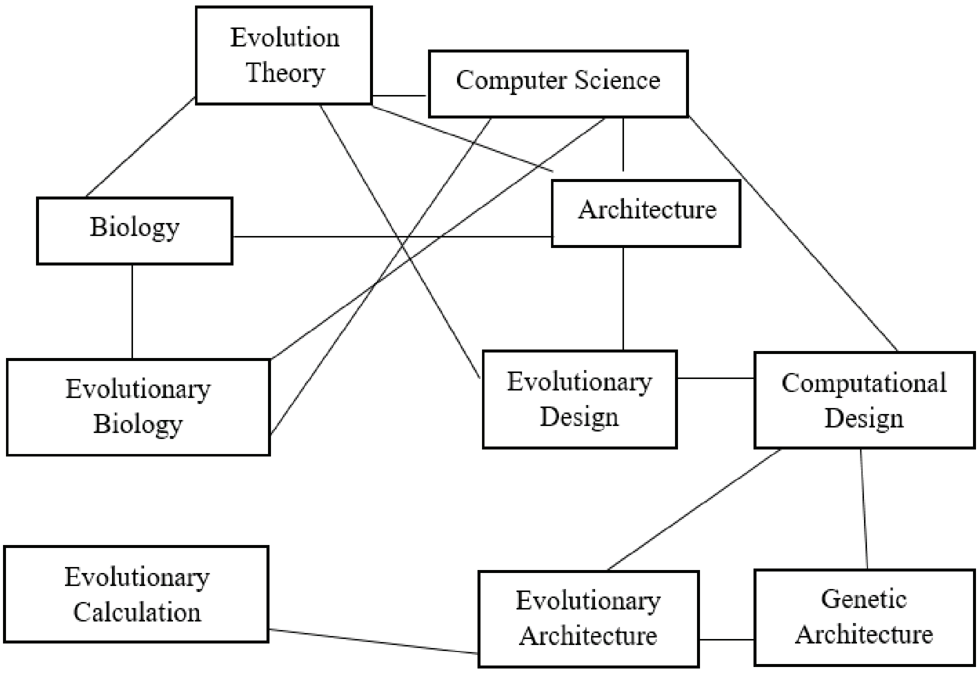

Diagram 4. Map of Influences for Bio digital Architecture Theories

We are capable of creating exceptional architectures in the 21st century that immerse themselves in their distinctive features. These conditions can be intensely ecological, systematically open-ended, intellectually founded, facilitating, time and period concerned, synthetic with natural landscapes, and use computational power not only as a means of representation, but as a spatial editing engine.

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Table 1. Bio-Method Formats

	Classical Method	Hybrid Method	Living Method
Chronology	…20th century	21st century onwards	A possible future (22nd century)
Movement	Bio-mimesis	Bio-digital design	Neoplasmatic design
System type	Controllable	Changes with user need and thinks on behalf of the user	Maintains its existence and can be controlled by the user
Motion	Motionless	Motionless or semi-mobile. The motion can be controlled mechanically.	Mobile and motion can be controlled with genetic techniques
Behavior	Protects against unwanted natural conditions and isolates from the environment	Responds to nature the way the user wants. Limited by user insights.	Responds to natural conditions through its reflexes. The user can program the response during the production stage.
Relationship with Men	Men dominate the building; nature is outside the equation.	Men dominate the building; the building can respond to nature.	Men and buildings interact with nature.
Relationship with Nature	Abstract attitude against nature or similarity in terms of form	Functionally responsive	Creates artificial nature
Recyclability	Not recyclable	Not recyclable	Recyclable
Vitality	Nature=living City=semi-living Building=non-living Men=living	Nature=living City=semi-living Building=semi-living Men=living	Nature=living City=semi-living Building=unthinking-living Men=living
Production system	Masonry or structure with cover	Masonry/structure with cover and sensors	Unthinking, programmed organism
Material system	Traditional building material	Hybrid material, Traditional building material mixed with a living organism	A living organism as a material

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BIO-PARAMETRICAL STUDIES

Natural means living. So, how can we reflect liveliness into design? Is it about imitating life or being alive? How can we use biological data for design? How can we make time visible in buildings? These are the questions that are addressed in these experiments.

To see time in a biological structure equal to the growth of an organism leads us to buildings having a lifecycle. Although they have it, once a building is destroyed, it doesn't blend in with nature. With the usage of natural materials, recyclable and composable buildings become a possibility. The first step for such design starts with having symbiotic relationships between living and the artificial. Crossbreeding organic and artificial life leads to hybrid methodologies.

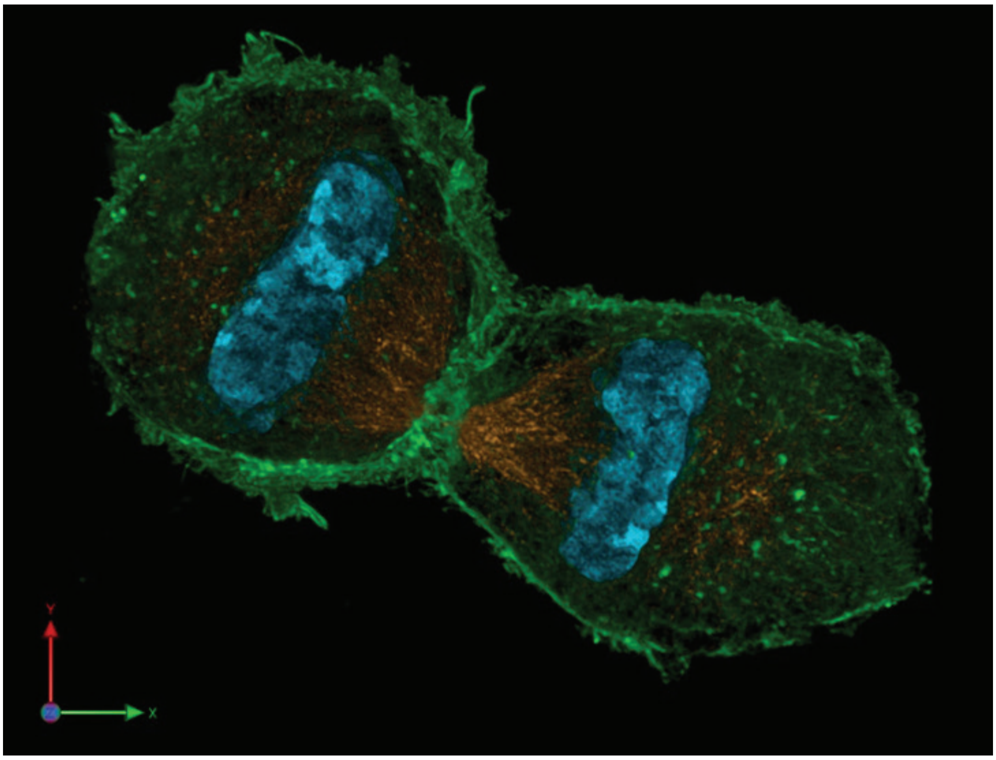

Figure 1. Image of a Cell during Mitosis[3], which is a Form of Autopoiesis

3 https://bio.libretexts.org/Bookshelves/Cell_and_Molecular_Biology/Book%3A_Cells_-_Molecules_and_Mechanisms_(Wong)/15%3A_Cell_Cycle/15.06%3A_Mitosis

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Mitosis is a biological process where a single cell divides into two identical cells which can also be called cell division. This process has similar qualities to autopoiesis which is self-creation (Figure 1). This term refers to a system's capability to reproduce and maintain itself by creating its parts and further components. This self-creation process could be an inspiration for self-organized systems, even autopoietic buildings. Biology-inspired design methodologies often include attributes of biological organisms. These attributes can be called bio-parameters and these parameters can be used in bio-design (Table 2).

Table 2. Bio-Parameters and their Definitions

BIO-PARAMETERS	
Growth	Progressive development of an organism
Morphogenesis	The biological process that helps a cell define its shape
Evolution	Change in a generation of species as a result of natural selection
Mutation	Change or alteration in the genetic material
Symbiosis	Variety of organisms sharing the same environment and living together
Self-Organization	The process of adapting to the environment for the development of a particular function of the internal order of a system without any external control or direction
Adaptation	Organisms adjust their qualities such as structure, genetics, and physiology to fit their environment

FINDINGS 1. FUNGAL SURFACE EXPERIMENT

As a part of experimenting and studying bio-parameters concerning design, two projects were initiated. The first one, Fungal Surface, consists of studies on bread mold and using growth as a design parameter. The project encompasses a future scenario where global warming and the big amounts of Sun rays disrupted organic life and humans need to protect themselves from the Sun. To do that, they need to live in underground cities, where moisture is enough for mold to multiply. In this scenario, the surfaces are made from genetically engineered molds to avoid harmful effects on the organism and control its growth.

The first step for this study was to observe a bread mold and study the colonization and communication between different cells. The layers of bread mold were defined considering to use of them as a biological structure. Mycelium in molds consists of many thread-like or fiber-like structures known as Hyphae. It's a reticulated structure that creates communication networks and they move collectively (Diagram 5).

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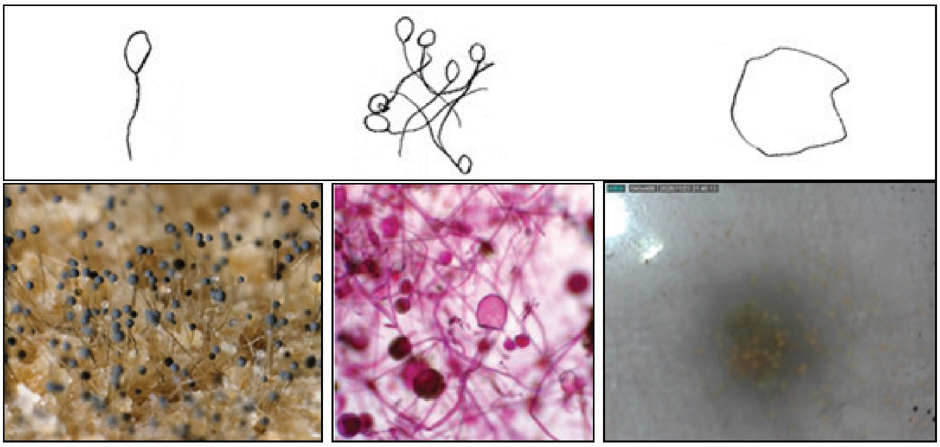

Diagram 5. Layers of a Bread Mold: Singular-Networks-Collective

Molds started appearing when food (bread) got deteriorated and they continued to reproduce as long as there was food (Figure 2). With the help of the microscope, the morphology and colonization of the mold were observed.

Figure 2. Food Decay and the Appearance of Molds

After a period of growth, the molds started to create a pattern and distribution of density according to the location of the food source (Figure 3). The density amongst the colony occurs where there's nutrition and the farther away a cell is from its food source, the harder it is for that cell to survive.

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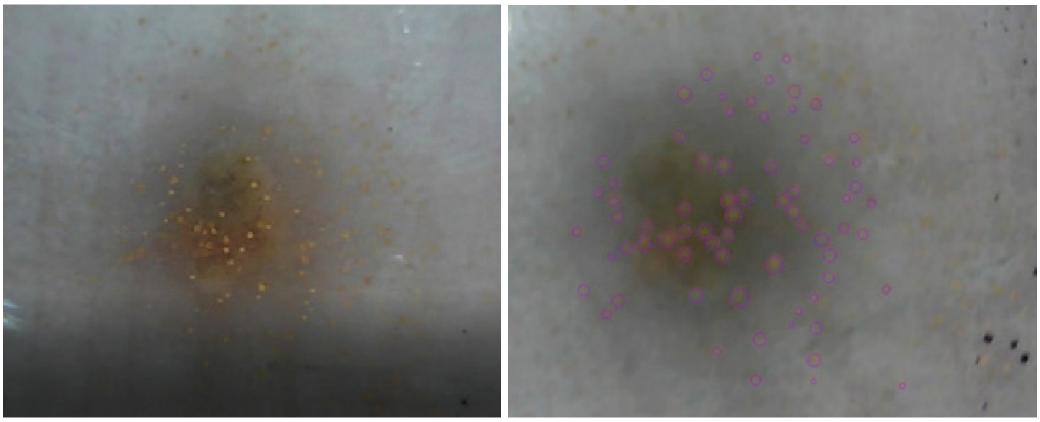

Figure 3. Images Showing the Distribution of Cells

To carry this experiment into the digital environments, observations were translated into diagrams since visual language tools are important to convey concepts for designers. The distribution of cells was marked with points which were then used for Delaunay triangulation (Figure 4, Figure 5). Two different diagrams emerged from two molds fed from the same food source and grew in the same environment.

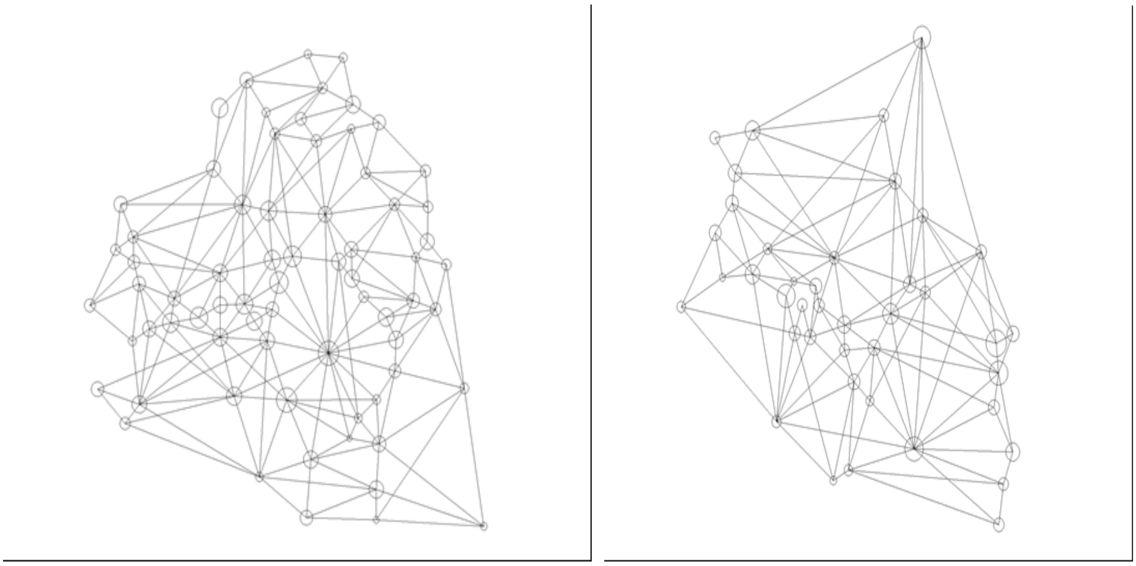

Figure 4. Delaunay Triangulation of the Mold

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The first mold was selected for the study since it contains differing densities that could increase the chance of variety in design which would lead to originality. Different levels of densities were divided into regions in a sketch (Figure 5). Later, this study was carried into a digital platform for more precise calculations (Figure 6).

Figure 5. Regional Sketch Showing the Density of Population

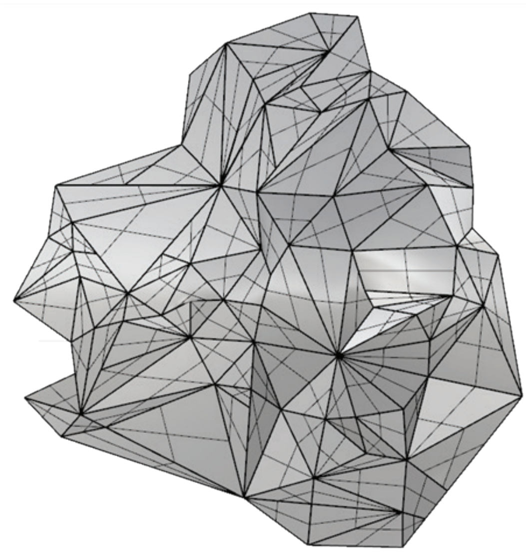

Figure 6. Fungal Surface Front View

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Fungal Surface is designed vertically to imitate a living wall system. The parts of the system are fluid and respond and react to the environment. In case of a natural disaster such as a flood, the open parts of the system will be closed to avoid water entering. Another example includes an earthquake scenario in which the surface will bend and curl to protect the inhabitants and avoid any collapse (Figure 7).

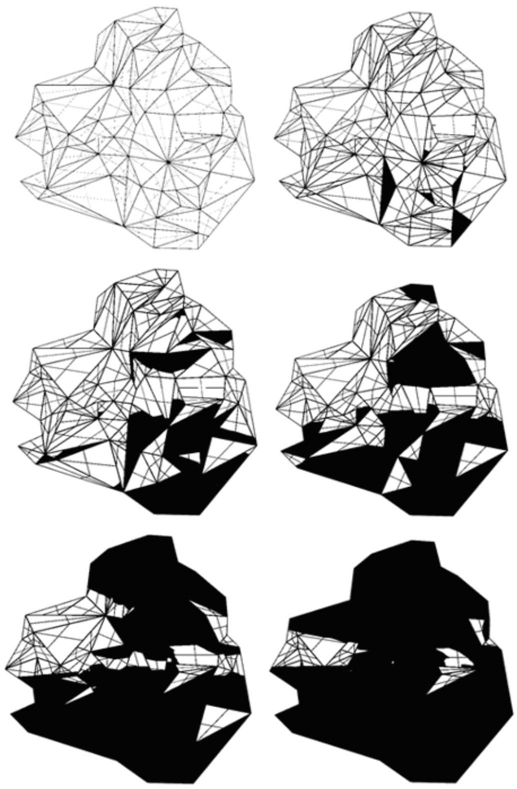

Figure 7. Fungal Surface Reacting in a Natural Disaster Scenario

FINDINGS 2. NEOPLASMATIC SPACE EXPERIMENT

Neoplasmic Space is a continuation of Fungal Surface and proposes co-growth of user and structure, establishing a relationship between the user's DNA and the structure's DNA. As the user grows, the space grows simultaneously as a result of the increasing movement in the area, taking form according to needs (Figure 8). Spaces are interactive with the user and the environment. The building takes shape by responding to user needs.

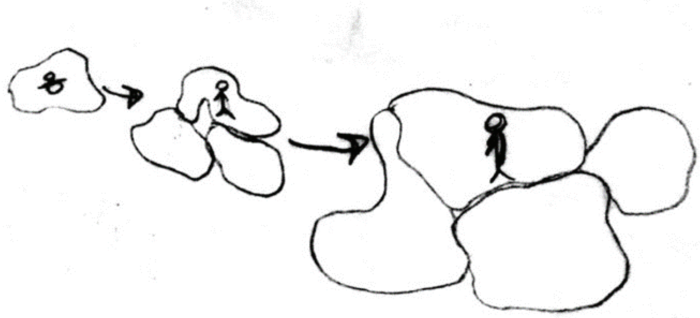

Figure 8. Concept Sketch of Neoplasmic Space

It’s designed as a modular structure since different modules embody different qualities resembling the relationships between cells of an organism (Figure 9). The modular structure consists of unique modules integrating. The modules don’t have to resemble each other since they all have different codes, so the system is a symbiosis between them.

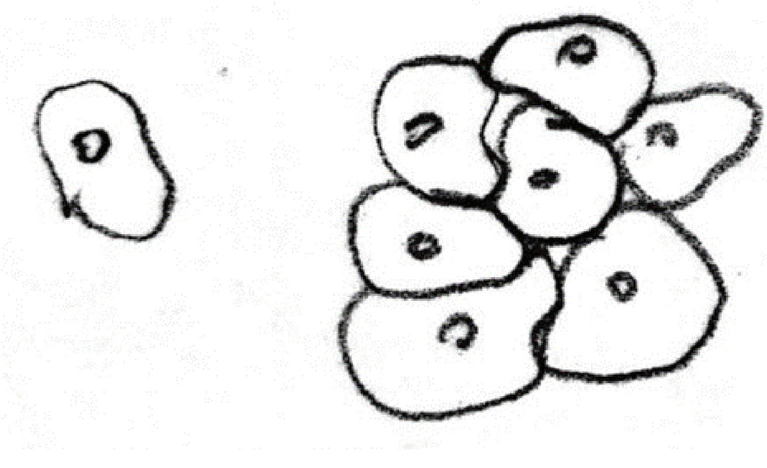

Figure 9. Sketch Showing the Single Module (Cell) and the Modular Structure

Since Neoplasmic Space is a continuation of Fungal Surface, the previous model was improved. The Delaunay triangulation process was supported by the Voronoi diagram technique. After determining the centers of the triangles, polygonal patterns were created by connecting them (Figure 10).

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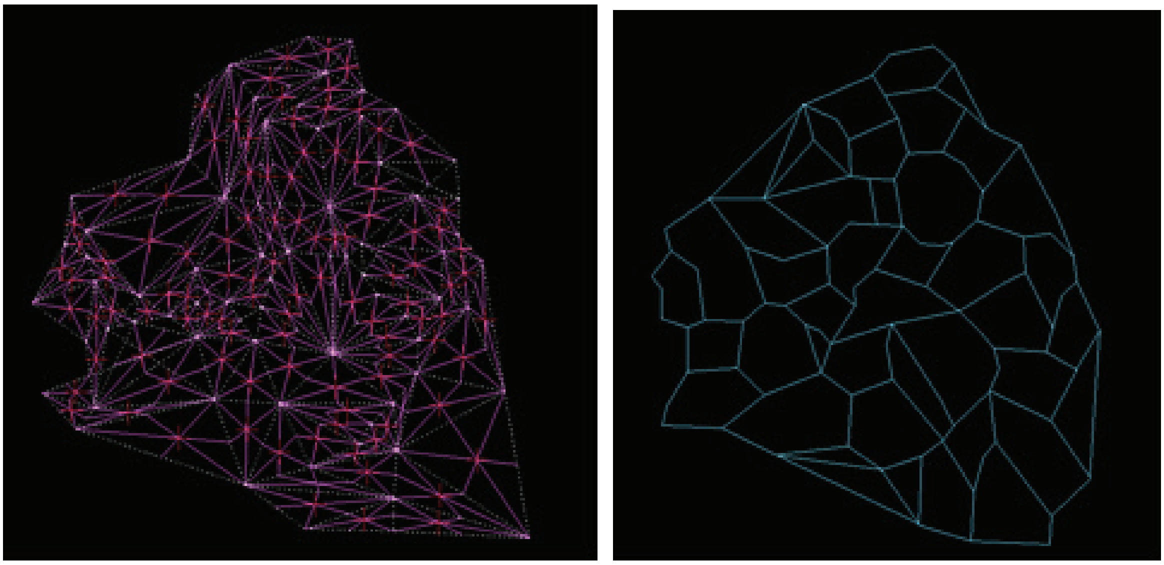

Figure 10. The Formation Process of Neoplasmic Space

The modular framework is based on the Voronoi diagram study. With the help of using the point cloud system and having a variety of levels according to previous observations about the mold, surface articulation was made (Figure 11, Figure 12, Figure 13, and Figure 14).

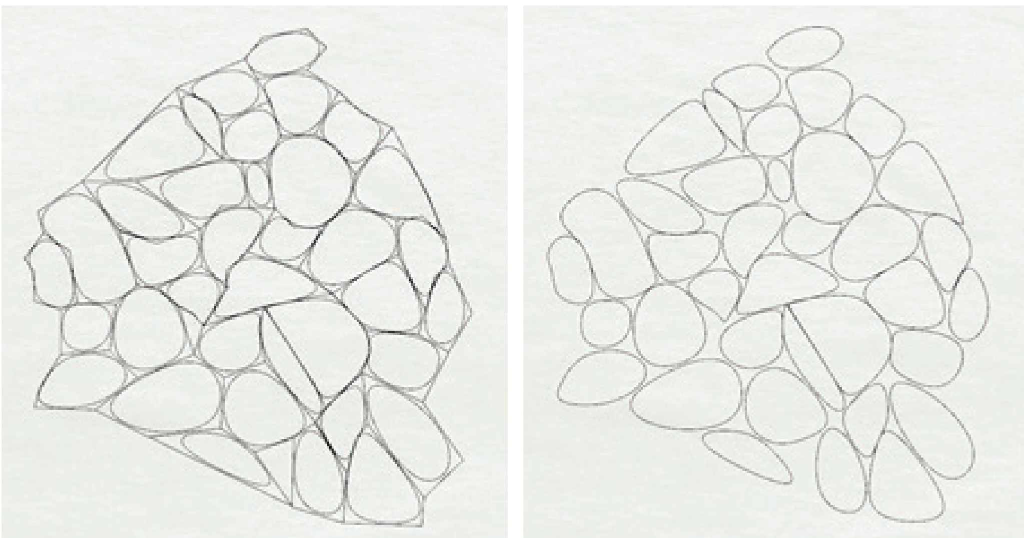

Figure 11. A Cellular Framework of Neoplasmic Space

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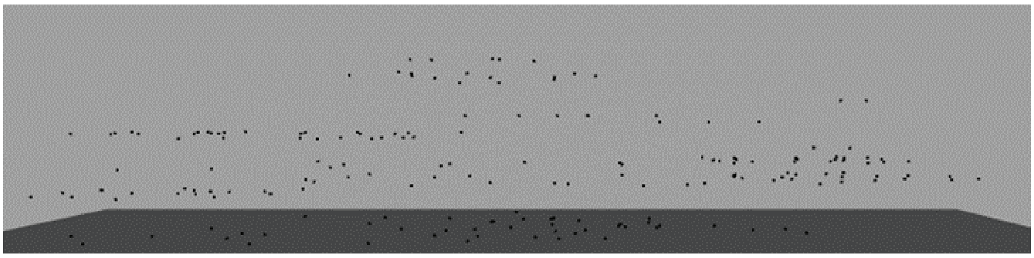

Figure 12. Point Cloud System of Neoplasmic Space

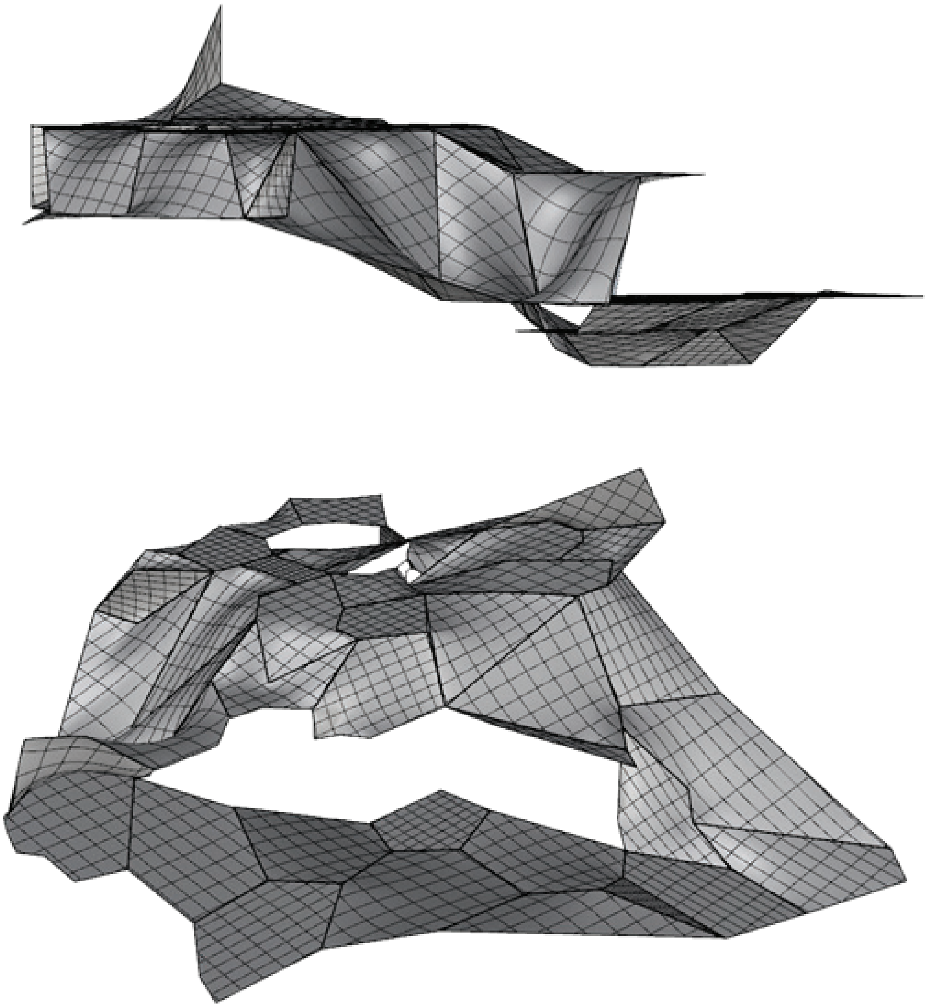

Figure 13. Surface Articulation of Neoplasmic Space

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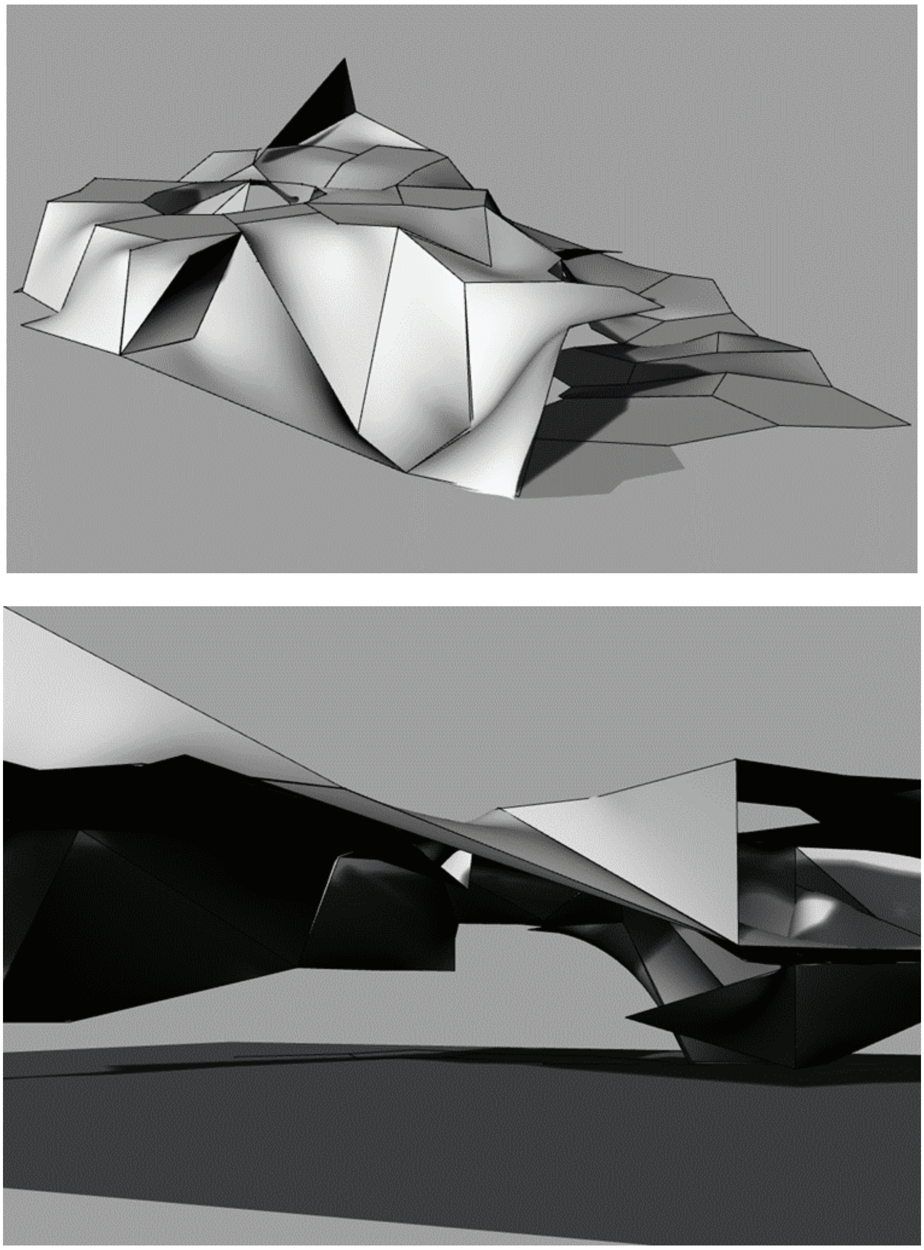

Figure 14. Perspective Views of Neoplasmic Space

What Neoplasmic Space proposes is not a finished form but a fluid one that could change depending on environmental factors and user needs. Each module communicates with each other as well as the environment and users which makes the

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system work as a whole. Its self-sufficient quality allows it to exist in all kinds of environments and produce energy if needed. Since it contains living organisms as a building material, it can renew and regenerate itself in case of any damage. The system works as a whole like a collective intelligence and responds to user needs.

DISCUSSION

As architects, the design methods we base on nature should go beyond analogy, and for this, we need to turn to the joint work of biology and architecture. The creation of semi-living architectural structures offers the opportunity to activate the sensitivities of natural dynamic mechanisms that are missing in artificially produced systems and to benefit from natural systems.

The first step towards a new future was biomimicry, the imitation of nature but its time is over, and with the new information and technologies, the future of architectural design changes. Since there can't be a harsh transition from artificial space to organic space, hybrid spaces or semi-living spaces come next. Early examples of this theory are discussed throughout the research. As a prediction, the last step could be buildings being alive, however, not thinking on their own. This is of course a matter of debate and should be considered ethically since hybrid spaces and methodologies involve the use of living material as a building block. In such an approach, human-induced alteration of bio heritage is in question. Although altering the environment would be ethically questionable, it's been done since the agricultural revolution, and we can see the results of corruption, especially with global warming. However, if the aim is to build a better world, a positive kind of intervention shouldn't be an issue. Nature has its way to survive and as human species and a part of that nature, we can develop new methods to keep on living.

RESULTS

The observed growth process is transferred to geometry by diagrams. The focus is on the moments when the character of the biological structure changes during the transformation process. These are expressed in diagrams as points and lines. Coding the sensitivity of evolutionary time while creating the biological structure provides this information with an opportunity for more sensitive spatial thinking and/or geometry. What might be problematic here is that this thought and/or geometry is translated into geometry without time, that is, without relation. Such shorthand inferences can often result in a reduction. The main thing here is that the designer increases the biological information as much as he can control it. While designing the space with increased

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information geometry, the designer also discovers new and creative possibilities. The strategy used is flexible for designing at different scales such as industrial design, product design, fashion design, urban design, etc. Whether the body of the biological structure will be related to a human body or the city working like an organism through the relationships discovered, it can be beneficial for designers working at these scales to develop design methods.

Hybrid methodologies involve biological materials infiltrating the design and not fully replacing the building with an organism. The aim is to create a hybrid between biology and design. Architectural products aren't seen as a living system, but it could be with the blurring of the limits between architecture and biology. The building blocks in design could be programmed as cellular matter and since the cells act like living organisms that grow and evolve, the building could also evolve even structure itself, re-structure, and adapt according to its environment. Change is the most noticeable quality of a living organism therefore seeing a change in an architectural product could turn it into a semi-living being almost. Understanding different biological processes from the molecular level to their ecological roles will enable efficient use of resources and more sustainable designs. It is stated that using molecular biology, structures can be grown by following the instructions in their genetic codes, and mutations can be created in structures by adaptation to natural processes such as evolution or natural selection to structures. This could be achieved by programming the cell and eventually the structure or incorporating a living material with the structure and hybridizing the design. The most important step in such a design process is that the designer can develop the local rules that enable the self-fictional whole they planned to emerge and define them through the spatial interfaces to the individuals (organisms) who make up the system. Then all that remains for the designer will be to watch the whole build itself. In this way, we can produce living structures that are aware of their surroundings and can interact with them, heal, develop, and most importantly, can be programmed to construct their specific target structures in a self-fictional way. Moreover, the fact that the basic building blocks of such structures are living cells that can reproduce themselves permanently means that the architectural material we have will constantly renew itself. Such a technique will not only provide solutions to many problems on our planet but also contribute to space architecture (Figure 15).

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Figure 15. Neoplasmic Mars Vision

The conclusion reached within the scope of the research is that hybridized structures with biological materials will become widespread in the future. The connection between the living and the artificial lays the groundwork for semi-living architecture. With advanced technologies, it may be possible for the material to grow and build itself which gives unique qualities to the design. No design will be the same as the other, leading to one-of-a-kind, original buildings that are locally specific and that contribute to the environment, making life better for all creatures.

SUGGESTIONS

To achieve accurate calculations and experimentation, it's necessary to establish a laboratory environment for the studies that were held in this research. With the such environment, the parameters mentioned in this study can be better controlled and improved. Also, numerous experiments should be carried out to have the best results and avoid miscalculations that might occur during the physical trials.

REFERENCES

AYMELEK, Y., ÖZGENCİL-YILDIRIM, S., (2015). Çağdaş Mimariyi Etkileyen İki Metafor: Form Fonksiyonu İzler ve Form Akışı İzler. Beykent Üniversitesi Fen ve Mühendislik Bilimleri Dergisi, 8(2):33-60

CRUZ, M., (2008). Cyborgian Interfaces. Architectural Design, 78(6):56-59

CRUZ, M., (2008). Synthetic Neoplasms. Architectural Design, 78(6):36-43

CRUZ, M., PIKE, S., (2008). Neoplasmatic Design: Design Experimentation with

Bio-Architectural Composites. Architectural Design, 78 (6):6-15

FRAZER, J., (1995). An Evolutionary Architecture. Architectural Association Publications, pp.11-15.

KWINTER, S., (1993). Soft Systems. In Boigon B., Editor, "Culture Lab", Princeton Architecture Press, pp.212-213

LYNN, G., (1999). Animate Form. Princeton Architectural Press, pp.10

PIKE, S., (2008). Manipulation and Control of Micro-Organic Matter in Architecture. Architectural Design, 78(6):16-23

PIKE, S., (2008). Algaeculture and Nonsterile. Architectural Design, 78(6):16-23

PIKE, S., (2008). Contaminant. Architectural Design, 78(6):24-29

REED, P., (2004). Biomimicry. The Technology Teacher, 63:23-27

SELÇUK, S.A., SORGUÇ, A.G., (2007). Mimarlık Tasarımı Paradigmasında Biomimesis'in Etkisi. Gazi Üniversitesi Mühendislik-Mimarlık Fakültesi Dergisi, 22 (8):451-459

TURNER, J.S., (2012). Evolutionary Architecture: Some Perspectives From Biological Design. Architectural Design, 82 (2): 28-33

WATTS, B., AFFLECK, S., (2008). Living Buildings. Architectural Design, 78 (6):78-79

WARK, B., (2019). Biophile: Yeşil Duvardan Fazlası. Arredamento Mimarlık, 327 (1):65-68

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