BIOMIMETIC ARCHITECTURE
A NEW INTERDISCIPLINARY APPROACH TO ARCHITECTURE

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ABSTRACT

As a highly interdisciplinary field, architecture is being influenced by many subjects of natural and social sciences. While many subject hold an indisputable effect on architecture, biological sciences is currently dominating the era. It is totally comprehensible for architects to observe, learn and copycat the natural phenomena on behalf of a better living. This biological framework evolved and shifted towards different approaches, especially with the advancements in the computer technologies and as a cause of this a better understanding of the nature's production methods. Especially, for the last 10 years, as many literature published and many studies done, this subject becomes more popular amongst architects. This paper aims to understand these design methods under the name of biomimicry and biomimetic architecture by reviewing the literature and research work done and examines these approaches under three categories like; biomorphological design, biomimetic design and biodesign as pointing out the differences between each approaches..

Keywords: *biomorphological design, biodesign, biomimicry, architecture*

1 INTRODUCTION

In the last 50 years, design and architecture has evolved (and continuing to evolve) to a different phase and tried to push its defined borders and started to think and act with other disciplines. In this highly interdisciplinary era, it is inevitable not to integrate different professions and disciplines into the theoretical and practical universe of architecture. Amongst many subjects; natural sciences such as physics, mathematics, computer science, chemistry, social sciences, contemporary engineering topics, etc. have irreversibly affected architectural thinking. While many subjects hold an indisputable effect on architecture, it is the experiments of biological sciences who have achieved the strongest momentum, inciting the ongoing research and innovation in many subfields of architecture. Within the current degradation of the environment, nature and biology provided a good theoretical and practical framework to the designers or architects, who faced an urgency to alter their methods and reprioritize their goals (Myers, 2012).

It is possible to see signs of this particular science in architecture, since the ancient times when the first architectural artefacts were created. It is only natural and totally understandable, for the mankind to observe and mimic and/or imitate the natural phenomena to build a shelter for its own kind. However, most of the time, this kind of mimicry lacks the innovation of a real biomimetic building today we are talking about. In that situation, biomimicry is interpretation of an architectural style, reflected in the overall form. (Jeronimidis & Gruber, 2012) Biomimicry as an architectural style, stays as a mere analogy of a natural form, not considering or generating the knowledge of its biological functions, and defines the entirety of a building. It is almost impossible to see any traces of biological knowledge. This kind

of imitation of nature in architectural design is an old fact as mentioned below but it is used especially in the stylistic movements such as Art Nouveau to the more recent Frank Gehry buildings. This approach is form driven, offering nothing but a decorative, stylistic of metaphorical effect. To summarize, it is only a formal mimicry of the nature and can be named as "biomorphic" architecture.

Another approach to biomimicry is a search for a new balance between nature and mankind. As the destructive relationship of architecture with the people and their environment becomes obvious, the idea of resembling ecosystems were presented by Frosch and Gallopoulos. (Frosch & Gallapoulos, 1989) This ecosystem resemblance idea were later researched and advocated by Janine McBenyus in her book Biomimicry: Innovation Inspired by Nature. The book argued that interdisciplinary partnership is necessary between scientific research and industrial technologies (or building technologies) to improve ecological performance. (Benyus, Biomimicry:Innovation Inspired by Nature, 1997) This kind of biomimicry exceeds an analogy and performs / functions in different levels (such as organism, behaviour and ecosystem) (Mazzoleni & Price, 2013). This approach was later integrated and expanded to architecture by Michael Pawlyn in his book Biomimicry in Architecture, where he defines biomimicry as "mimicking the functional basis of biological forms, processes and systems to produce sustainable solutions". (Pawlyn, 2011) The idea is to learn from nature and imitate it in the sense of ecological concerns.

A completely new approach in biomimicry, takes the idea further and harnesses living materials to create a living object and let nature run its own course. Myers, presents an emerging and a radical approach to design that incorporates the use of living materials into structures, objects and tools. Living organisms are essential components to enhance the function of the finished object. This approach goes beyond the idea of mimicking and integrates biology with the building literally to synthesize new hybrid typologies.

With the incorporation of architecture and biology three different approaches to design had arisen. Asides of the first, biomorphic design which is reflected on the whole form but nothing else, the two approaches mentioned above will push many interdisciplinary relationships to create a potential for positive impact, especially in ecological sense and may be the new paradigm shift for the "computer-dominated" architectural design field.

2 METHOD

Incorporating biology to problem-solving goes back since the beginning of the civilization when mankind has produced primitive tools by mimicking the nature. This has been expressed for more than a millennia and explored in the last decades with a scientific methodology. Besides these developments, there are serious social and physical issues such as global warming, waste, material and energy consumption, green gas impact, caused by the artificial processes. In the late two or three decades architecture, as an interdisciplinary discipline is trying to integrate this latest discoveries and theories of nature with a sustainable approach.

To depict how architecture integrated biology, this article will first examine (1) the definition of biomimicry to present three different approaches as (2) biomorphic design, (3) biomimicry, (4) biodesign and (5) discuss these terms of architecture by considering some examples of work done by architects in that sense.

2.1 Definition of biomimicry

The term biomimicry (bios: life, mimesis: imitation) first coined by Janine M. Benyus, an author and a naturalist from Montana, USA as "the conscious emulation of nature's genius." Benyus (1997) explains the foundation of biomimicry with 3 aspects of nature:

- Nature as model: Biomimicry examines the nature's models and imitate these designs for problem solving
- Nature as measure: Biomimicry uses the ecological balance to decide if the design is good or bad

- Nature as mentor: Biomimicry is not an approach to extract or gain from nature but based on "learning from nature".

Julian Vincent, defines biomimicry as "abstraction of good design from nature". (Pawlyn, 2011) The common point in this two definitions is, biomimicry to learn from the nature and transfer this knowledge to solve a design problem. Benyus (1997) extends this explanation and forms three levels of imitation. The first level of biomimicry is the mimicking of natural form. This type of mimicking is to copy an organism for its morphological attributes like its visual shape, components, materials or how it looks. In a single word, first level is to copy an organism's design. The second level is to mimic the natural processes. This level is to reproduce a biological entity's emergence or actions and processes within its environment. The third level is the mimicking of natural ecosystems. This is a more complicated set of processes than the first two levels. Mimicking ecosystems requires to consider not only the designed object but consider it in a bigger picture, how it affects its environment explicitly and implicitly. By expanding the sphere of influence, a true sustainable approach can be established.

Designs that occur in the nature resembles architecture discipline, when they are both considered to fit many different and clashing needs while they are both functional. Biomimicry provides a vast area of knowledge and it is a handy way to learn how a design emerges in the nature, to understand and reproduce nature's ways of productions, to create designs, materials, components, etc. to create a sustainable, closed energy loops. Gruber (2011) offers biology and architecture can be connected where innovation is needed in situations like; architecture is considered for new environments, solutions based on models provided by nature is needed, better relationship with the environment and living organisms is considered, investigation of better quality of life with simple solutions by optimising and adapting traditional solutions. This kind of connection and way of thinking provides a basic and important toolbox for a true ecological design approach.

2.2 Biomorphic Design

When architecture is taken into consideration, there is an obvious and important distinction between biomorphism and biomimicry at any level. (Pawlyn, 2011) For centuries, alternative approaches to architectural design based on form finding have been explored by some famous designers like Frei Otto, Eero Saarinen, Antonio Gaudi and such. After the Industrial Revolution when developments in natural sciences like physics, chemistry and especially biology have been dominating the theoretical and practical world. Therefore it was inevitable for architects to get inspired by these important developments, shifts in the world of thought. Many of them used nature as a source or inspiration for new, symbolic and unconventional forms.

Biomorphic (life-shaped) design or architecture has its roots in the works of the surrealists and Art Nouveau. A surrealist, Grefory Grigson, coined the term "biomorphism" in 1936 (n.a., Henry Moore, 2014) and it exists as a style since then and today it combines with the power of computation to achieve or to replicate the free-forms which can be seen in the nature. It is also related to the developments in science, especially in math as nature's geometry which can not be abstracted by Euclidian geometry, can now be explained by the help of fractal geometry. As we can unroll nature's way of creating edges, surfaces and volumes, it is also possible to apply this knowledge for form finding. But this type of form finding method misses one of the core requirements of the design engagement that is expected from the result. A form which resembles a living entity but the function is not adapted to this method. Because of that, it should be asked whether the result deliver the solutions that are required.

As a style, biomorphic design can be encountered in various geographies at various times. As Frank Lloyd Wright spoke of harmony between human artefacts and organic world, Gaudi in Spain tried to reflect the forces of nature on an organism and designed the famous La Sagrada Familia. Today this approach shifted towards a more scientific and elaborate design thinking. One example is from Medellin, Colombia called Orquideorama designed by Planb+ JPRCR arquitectos (n.a., 2008) (Figure 1) which is

influenced by the design of orchids. The organic approach is based on two different scales; (1) micro scale which holds the principles of material organization, defines geometrical patterns, (2) visual-external scale which allows to relate phenomenological and environmentally to the world. In this example, design approach is to reproduce a similar form of a bee hive and a forest but it stays just on a visual level.

Figure 1. Orquideorama is designed to define perception as a situation where visitors can feel the extension of a forest (n.a., 2008)

2.3 Biomimicry and Architecture

In the field of architecture, one can see many examples that is influenced/ learned from the nature. Constructions like branches of a tree, analogies of flowers, network configurations, etc. inspired the architectural design thinking since the ancient times. This inspiration can be observed in two ways; (1) to reproduce the form with the concern of form finding, (2) or to transfer the process of emergence of a living entity (like material, form, structure, etc.) to design thinking. The first is mentioned in the previous chapter as it is just a concern of form finding and most of the time does not refer to a functional and an ecological approach. The second way is a different approach though, which offers to observe and understand the functionality and harmony within the nature.

It is important to understand how each living thing has its own functionality to create a nest to survive in its environment, to endure its conditions but performing this with harmony and causing no harm to its environment. These nests are built with instinct, as lightweight, stable, energy efficient dwelling based on a genetic knowledge. Emergence of these natural forms inspired architects and designers to study and research the field of biology and ecology to harness the nature's way of construction in a global network of harmony, with the objective of creating a sustainable and an ecological built environment. Examples may vary; like the material of a seashell or spider web's endurance, geometries and spatial relations in a beehive, photosynthesis' to harness energy from sun, etc. These examples all point out the wisdom behind nature (Alison, Brayer, & Spiller, 2003).

Biomimicry inspires architecture in different levels as biology does in the nature and these levels can be summarized under three categories: (1) form, (2) process, (3) ecosystem. Form and processes can mimicked in an ecosystem. Benyus (1997) explains these levels with the example of an owl's feather. Feather can be replicated by its formal attributes but this will not lead to an ecological and a sustainable solution. This is similar to biomorphic approach but the distinction between them is the process. If the process is mimicked it is possible to achieve the properties of the feather; how it is produced without using toxic waste or high energy consumption and how it affects the body heat and energy conservation. The third level is the ecosystem level, explaining how the bird and the feather exists together in a larger biosphere with other organisms. This approach is methodized by Zari (2007) to apply to a design or an architectural problem. The three levels mentioned above are rearranged and seperated into sublevels (See Table 1) and explained how biomimicry is considered for a design problem.

Table 1 A Framework for the Application of Biomimicry (Zari, 2007)

Level of Biomimicry		*Example - A building that mimics termites:*
Organism level (Mimicry of a specific organism)	*form*	The building looks like a termite.
	material	The building is made from the same material as a termite; a material that mimics termite exoskeleton / skin for example.
	construction	The building is made in the same way as a termite; it goes through various growth cycles for example.
	process	The building works in the same way as an individual termite; it produces hydrogen efficiently through meta-genomics for example.
	function	The building functions like a termite in a larger context; it recycles cellulose waste and creates soil for example.
Behaviour level (Mimicry of how an organism behaves or relates to its larger context)	*form*	The building looks like it was made by a termite; a replica of a termite mound for example.
	material	The building is made from the same materials that a termite builds with; using digested fine soil as the primary material for example.
	construction	The building is made in the same way that a termite would build in; piling earth in certain places at certain times for example.
	process	The building works in the same way as a termite mound would; by careful orientation, shape, materials selection and natural ventilation for example, or it mimics how termites work together.
	function	The building functions in the same way that it would if made by termites; internal conditions are regulated to be optimal and thermally stable for example (fig. 6). It may also function in the same way that a termite mound does in a larger context.
Ecosystem level (Mimicry of an ecosystem)	*form*	The building looks like an ecosystem (a termite would live in).
	material	The building is made from the same kind of materials that (a termite) ecosystem is made of; it uses naturally occurring common compounds, and water as the primary chemical medium for example.
	construction	The building is assembled in the same way as a (termite) ecosystem; principles of succession and increasing complexity over time are used for example.
	process	The building works in the same way as a (termite) ecosystem; it captures and converts energy from the sun, and stores water for example.
	function	The building is able to function in the same way that a (termite) ecosystem would and forms part of a complex system by utilising the relationships between processes; it is able to participate in the hydrological, carbon, nitrogen cycles etc in a similar way to an ecosystem for example.

2.4 Organism Level

In this level, solutions related to efficient energy usage and materials which are established already. In brief, it is mimicking an organism's physical attributes. An example at this level, based on mimicry of form and process is Waterloo International Terminal (See Figure 2) design by Nicolas Grimshaw & Partners. Considering its high span, the terminal need to respond to dramatic pressure changes as the train arrival and departure. Because of that glass panels are arranged like the scale of a pangolin, to adapt the imposed air pressure (Zari, 2007). Replicating an organism level is related to specific features to solve a certain specific problem thus biomimicry is not integral idea of a design and design may remain conventional. The design may result with a new, fancy looking building but ecological outcome is not necessary at this level.

Figure 2. Waterloo Internation Terminal and glass panels mimicking a pangolins outer shell (scale) (transformKC, n.d.)

2.5 Behaviour Level

Mimicking in a behaviour level can be achieved to explore and understand how an organism relates and behaves in its own environment. It is possible to understand this level with observing how an organism tend to operate in its environmental capacity and within limits of energy and material availability. (Zari, 2007) Termites are the most common example to explain this level. As seen in Table 1, in behaviour level termites build their nests to protect and stabilize the heat of the fungus combs at 30 degrees Celsius despite the 21 degrees range in temperature, where they store the fungi they produce. Because of that termites build a 13cm tall ventilation channel which ventilates the hot air outside and cold air inside (See Figure 3) The Eastgate Shopping and Office Center in Zimbabwe uses the same behaviour to naturally heat and cool the building to make it more energy efficient (n.a., Flower Pots and Biomimicry: Natural Air Conditioning, 2014).

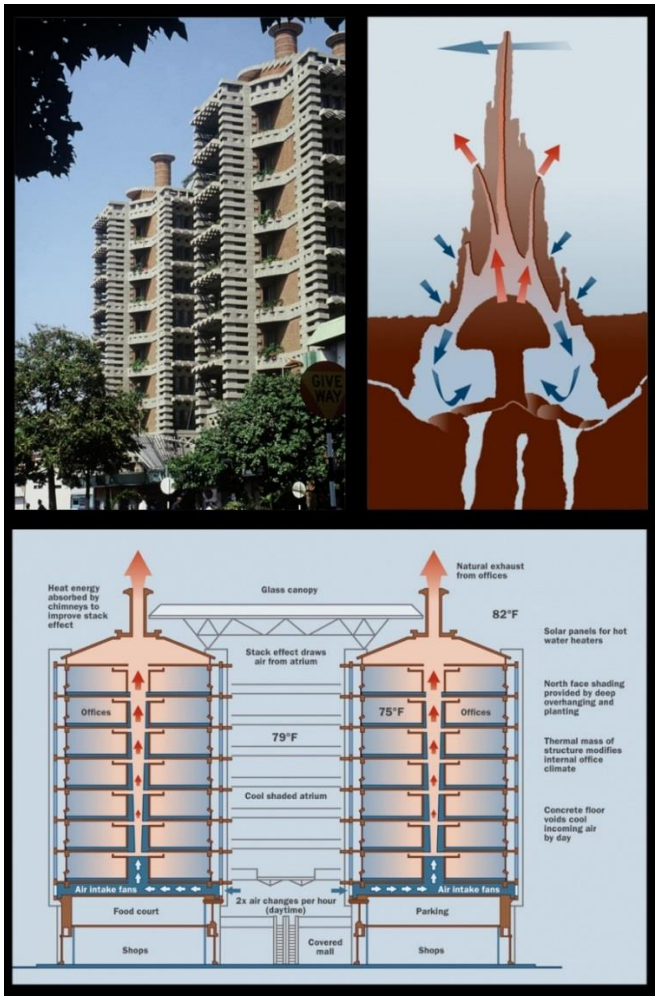

Figure 3. Appication of termite mounds to achieve a natural ventilation in Eastgate Center;(Photograph: © David Brazier. Illustrations by Daniel Gallant/Foundry Zero. Adapted from artwork courtesy of Mick Pearce.)

Behaviour level mimicry can not be suitable for all situtations and context should be taken into consideration. A suitable behaviour for a living organism may not be suitable for all the time.

2.6 Ecosystem Level

This level of biomimicry intends to create a whole ecosystem which incorporates the other two levels to achieve a sustainable environments.This means a deep comprehension of ecology and the regenerative processes of the nature. This level may begin from a small scale and tends to lead to a bigger scale of thinking like green cities or eco-cities.

3 BIODESIGN

A third approach to biology and architecture integration is biodesign or in other terms bioutilisation. Pawlyn explains bioutilisation as the direct use of nature for beneficial purposes, such as incorporating planting in and around buildings to produce evaporative cooling. (Pawlyn, 2011) In other terms biodesign is a design thinking which incorporates biological processes. Biodesign claims to go further than other biology-inspired approached to design and also fabrication. Unlike biomimicry or biomorphism, biodesign refers to the incorporation of living organisms as essential components, enhancing the function of the finished work. (Myers, 2012) It goes beyond imitation. But this design approach is now at an experimental level to create a drastic change in the architectural environment. There is still a way ahead for architects to exploit the advances in biology, especially synthetic biology and biochemistry to build more ecologically. Nature was the only infrastructure at beginning of civilization and with the developments in biodesign architects may alter the nature to inhabit without doing any further harm.

4 CONCLUSION

In the current situation of the nature and the world, architecture as one of the most damaging activities of humankind, should change the way how it

thinks and operates to repair the damage that has been done before. Sustainable and ecological approaches have been dominating the architectural field as a trending topic but there is a danger that it may become a marketing tool. To research other fields and to incorporate them in the architecture discipline is important in that sense. It is needed because the how built environment is created needs a shift considering the current situation. Biology, as a natural science provides architects a framework how to consider a living environment, where they are designing. They have much to learn from the mutually beneficial habitat of other species.

Three approaches have been mentioned in this paper that present different levels of incorporation of biology. Biomorphism, alone becomes just another stylistic movement like the current marketing terms in architecture. But if it goes along with biomimicry, a rational, adaptive, efficient buildings become possible. It is mankind's duty to not to harm our environment and the ecosystem and besides that it is possible to regenerate the damage done by biomimicry and biodesign. Those two different approaches have an important common motive. To live without doing harm, to learn and respect the nature.

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