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Biomimicry as a sustainable solution in Architecture: Analytical study

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Abstract. Nature has been the primary inspiration for architecture since its very beginnings, and there are many facets and levels of this inspiration in architecture, starting from the stage of direct imitation of the formal aspects and proportions, passing through the aspects of masses and construction, all the way to the deep levels and principles upon which nature is based and achieving its sustainability. Therefore, the architecture, in the current time and for future times, is directed towards simulating the deep aspects of biological systems and taking advantage of their features, such as self-organization, adaptation, flexibility, and efficiency, in a way that achieves the desired goal of architecture, which is its sustainability. This is also through the emergence of the term (biomimetic), which the research focuses on for its ability to combine biology and architecture. From a review of the literature that dealt with this term, the research problem emerged as "the lack of clarity about biomimicry as a strategy aims at achieving aspects of sustainability."Hence, the research objective was defined by determining the possibility of benefiting from the trend of biomimicry as a tool and strategy for achieving sustainability while studying its applications in design and architecture. To achieve the research objective, a descriptive and analytical approach was adopted, in addition to several procedural steps, the first related to the theoretical aspects of the topic and building a theoretical framework for it. The second step was the practical study by analyzing a few approved projects. The last (third) procedural step was to draw results and conclusions. The research reached several conclusions that reflect the role of adopting the biomimetic approach in enhancing the efficiency and effectiveness of architecture and its sustainability and emphasizing the achievement of architecture responsive to environmental conditions by enhancing its natural systems to increase their efficiency and suitability to the requirements of development. The research also concluded that this approach will determine the path of contemporary and future architecture by approaching biological principles with architectural principles**.**

1 Introduction

Buildings are functionally a shelter as a physical containment for a person within his environment. This relationship has taken different paths and styles since architecture began as a response to its environment, passing through it being an artistic expression that mimics nature, all the way to what the relationship of architecture is witnessing today to imitate nature accurately. The presence of nature with the development of materials used in construction and design helped building structures to be more dynamic and mimic the elements of nature. The process of imitating or imitating nature, also known as biomimetic, involves finding creative solutions to design problems in architecture at several levels: some of which are related to the processes of imitating the forms found in nature, and some of which are related to imitating its functions and environmental systems in a way that confronts design challenges more sustainably and effectively. To be frameworks for nature's working systems and thus a productive and inspiring tool for reimagining the built world.

By presenting biomimetic as a design strategy that achieves aspects of sustainability, which is what the research seeks in order to form its own theoretical framework. For this purpose, the research used the descriptive analytical method, which includes a set of steps. They start with clarifying the term biomimetic and its aspects that achieve sustainability within levels, then these levels are investigated by following up on the latest specialized studies and analyzing them to extract the vocabulary and indicators of the theoretical framework. Then examine those aspects on selected samples within the application, and finally, results and conclusions are presented.

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2 Theoretical Framework and Methodology

2.1 Reasons to Approaching between Architecture and Nature

Architecture has continually drawn inspiration from nature. Bio-pluralism, which involves incorporating natural elements into design, has been present since the creation of man-made environments and continues to be relevant today. For instance, the ancient Greeks and Romans incorporated natural motifs, such as columns inspired by trees, into their designs. Similarly, the intricate patterns found in ancient and Byzantine Arabesque surfaces were influenced by the stylized forms of lichen plants. [1]

Organic architecture uses geometric forms inspired by nature to reconnect man with his surroundings. Kendrick Bangs Kellogg, an organic architect, believes, "Above all, organic architecture should constantly remind us not to take Mother Nature for granted - to work with her and let her guide your life. prevent it, and mankind will be the loser. ” [2] This aligns with another guiding principle, which is that the model should follow the flow and not work against the dynamic forces of nature. [3]

2.2 Characteristics of Linking to Nature for Architecture

When discussing architecture's relationship with nature, there are numerous aspects to consider. Organic structures found in living nature offer a multitude of benefits that can be applied in the field of architecture. Some of these advantages include:

2.2.1 Sustainability

In the late 20th and early 21st centuries, several architectural trends emerged with the goal of achieving sustainability by adapting to the natural environment. One significant trend is the simulation of nature, which aligns with the concept of sustainable development defined by the World Commission on Environment and Development in their report "Our Common Future." This concept aims to meet the needs of the present without sacrificing the ability of future generations to meet their own needs. This definition highlights two crucial elements.

First: ensuring the rights of the present generation without compromising the rights of future generations.

Second: protecting the natural resources and ecosystems for the benefit of both present and future generations. [4]

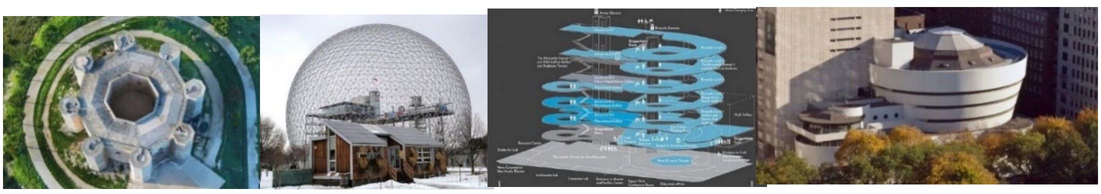
Perhaps "Sustainability”, as it relates to the environment, involves leaving the land in a good or improved condition after development, in order to meet the needs of future generations. This requires responsible development practices that do not deplete natural resources and cause environmental degradation. The most important sustainability goals are based on ecology - the science that studies the relationship of organisms to the environment [5] and social and cultural influences. To achieve sustainability, it requires a reduction in the use of resources and energy.[6]

Environmental researcher David W. Orr has divided sustainability into two categories: environmental and technological. While both aim to achieve sustainability, they differ in their approaches. Environmental sustainability focuses on preserving and protecting natural resources, such as ecosystems, minimizing waste, regulating climate, producing food, and managing resources [7]. On the other hand, technological sustainability involves using technology to transform resources into useful products while also incorporating scientific and design principles to align with human needs and the visions of designers in creating sustainable designs for the future [8].

2.2.2 Efficiency

2.2.2.1 Formal Efficiency

It is noted that nature's designs use the functional form and rely on the typical geometric design (design fractal) where beauty is hidden, and the design may extend without planning (Fig.1-A).[9]It also relies on network organization rather than linear (Fig.1-B).[10] Do not use borders and sharp edges (Fig.1-C). A variety of non-orthogonal shapes and design methods are used in construction to ensure maximum structural efficiency (Fig.1-C) and(Fig.1-D).[11]



A B C D

Fig.1. A /The use of the octagonal style in the design of The Castel Del Monte, Source: https://www.wiztours.com , B /The use of grid organization in the geodesic dome of Buckminster Fuller, Source: http://inhabitat.com, C /The museum path inside the

Guggenheim Museum, Source: https://www.guggenheim.org, D /The suitability of the Guggenheim's shape for the museum path inside it, and the smoothness of its shape and its lack of dependence on sharp edges, Source: https://www.guggenheim.org

2.2.2.2 Structural Efficiency

In nature, we can observe the use of ordered and hierarchical structural systems. These systems rely on diversity, adaptability, flexibility, and dynamism. They are present at all levels, from the atom to the galaxy (see Fig.2).

Fig. 2. The use of the square as a repetitive unit, its use in structural construction and in the interior and architectural design of the Benik Library Building at Yale University, source: http://beinecke.library.yale.edu

2.2.2.3 Eco-efficiency

Natural systems respect ecological boundaries, adapting to time and space. Nature designs respond to the variety of environmental factors that affect them (Fig.3-A).[12] It relies on natural sources, especially sunlight (Fig.3-B).[12] It also remains in equilibrium with the surrounding bioclimate (Fig.3-B) (Fig.3-C).

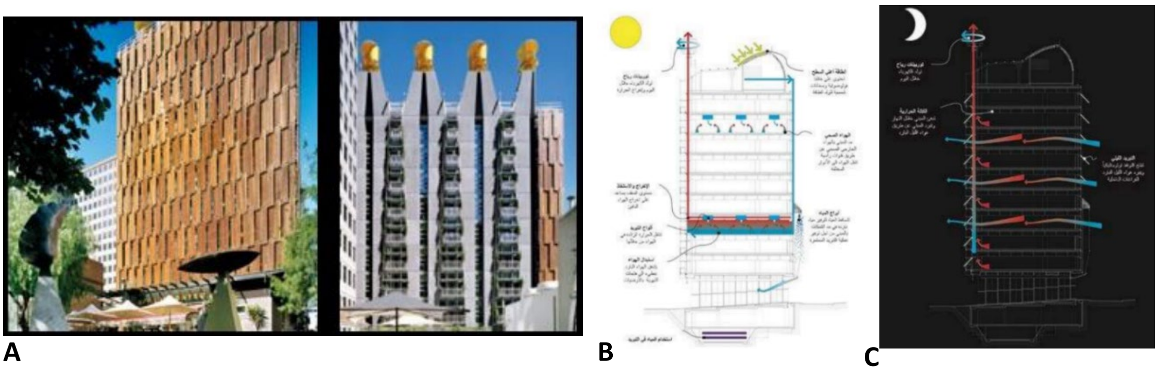


Fig. 3. A /The response of moving panels on the facade to the sun , to provide comfort to users in the CH2 building, Source: http://www.architectureanddesign.com.au , B / The process of generating energy in the building and how to gain and lose heat during the day in the CH2 building, Source: http://www.architectureanddesign.com.au ,C /The process of generating energy in the building and how to gain and lose heat at night in the CH2 building, Source: http://www.architectureanddesign.com.au

2.2.2.4 Material Efficiency

Natural systems rely on full recycling, where the waste of some species is food for others , which helps to achieve the concept of zero waste ((Zero Waste). They also use the necessary materials and avoid overuse. Nature's designs rely on reducing and minimizing rather than maximizing, by using fewer materials while optimizing function and creation.

3 Biomimicry

There are numerous concepts related to drawing inspiration from nature, and one example is biomimicry, as defined by Vincent [13]. According to The Institute of Biomimicry, biomimicry is an innovative approach that aims to find sustainable solutions to human challenges by imitating patterns and strategies that have been successful over time. This involves creating new products, processes, and policies that are well-suited for long-term survival on Earth. The underlying concept is that nature has already solved many of our problems, and animals, plants, and microbes have served as the architects through billions of years of research and development. Failures in nature are preserved as fossils, and the key to survival is all around us [14].

3.1 Simulation Levels

According to Zari, there are three levels of biomimicry: organism, behavior, and ecosystem, which can be studied through existing biomimetic techniques. Each of these levels is further divided into five dimensions: appearance (Figure), composition (Material), method (Construction), movement (Process), and purpose (Function) (Fig.4) [15]. The simulation levels are categorized into organism, behavior, and ecosystem, and will be further elaborated on below.

1- Organism Level: This level involves simulating a specific organism, such as a plant or animal [16], and can include simulating either a part or the entire organism [15].
2- Behavior Level: At this level, the focus is on simulating or translating an aspect of an organism's behavior [15], such as how it behaves to survive or reproduce [16].
3- Ecosystem Level: This level involves simulating a particular ecosystem and its successful functioning [16], as well as identifying the essential elements and principles necessary for its success [15].

3.2 Simulation Dimensions

Each level is divided into five different dimensions [15]:

- Form: This dimension is based on the morphogenetic imitation of a biological organ or system. While there should be a clear visual similarity between the building envelope and the biological object or system that inspired it, it is not necessary for the building to have a functional advantage that directly reflects this inspiration [17].
- Materials: In the simulation method, the building is made of the same materials as the thing that it mimics in nature, or from which the ecosystem in which the building is located or the system that it mimics, is made.
- Construction: The building must be in the same composition or style as the organism or organ, or it must be built in the same way in which the organism is built in its environment, or how it meets with the rest of the organisms in the ecosystem.
- Function: This dimension focuses on mimicking the biological mechanism of the organism or system. This means that the building's interface should prioritize function over form, although it may also share a similar shape. This is achieved by incorporating the principles of the biological function into the technology used in the building, or through a process of abstraction and extraction [17].
- Process: While an important aspect of nature simulation, this dimension is not typically found at the level of individual buildings. Instead, it is more commonly seen in the linkages between buildings at the urban level [17].

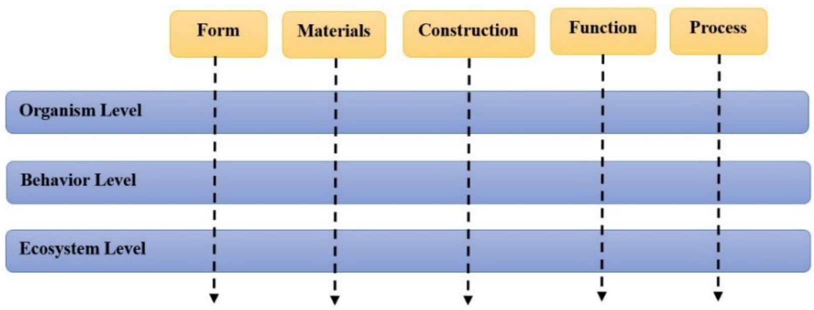


Fig. 4. Framework for biomimetic applications, Source: Researcher

4 Theoretical Framework for the Biomimetic in Architecture

To establish a comprehensive understanding of simulating living natural systems and their sustainability, this study aims to build an information base and theoretical framework. To achieve this, the study will examine several specialized studies, including the following:

4.1 (Van der Ryn, 1986) "Van der Ryn, Sim "Sustainable communities: New design synthesis for cities, 1986

The study referred to ecological design, which means meeting human needs and preserving the natural environment, including site planning, energy design, gardens, construction...etc. The study clarified the purpose of ecological design, which is to combine nature and technology, using ecology as a basic basis in design. Strategies for energy conservation, regeneration and renewal can be applied at different levels of scale to produce a revolution in the forms of buildings, natural spaces, communities, cities, and the application of technology. Therefore, the study indicated that ecological design represents a concept about creating unified design solutions and a link between nature, culture, and technology to integrate and unify human needs. Society in balance with nature. Pointing to the basic processes in ecological design, which are represented by designing the place and the project with the basic nature of the design. The use of geometry is not only to organize space and indicate social interactions, but also to create balance with natural spaces.

4.2 (Jencks , 1997) Jencks, Charles, “The Architecture of the Jumping Universe” , Editions, 1997

The study indicates that there are many attempts to link architecture with nature, starting from the ecological orientation towards curved and continuous organic forms, and this was reflected in the changes that occurred in the works of the architect (Rogers). The study indicated that architecture is moving from high techniques to organic techniques, as it is The basics of organic architecture are its compatibility with the surrounding natural environment and its imitation not only of the mass formation closest to nature, but also of the flexibility created by the natural environment by enhancing it with technology and energy economy, and this is what is called the concept. (techno_organic)

4.3 (Yeang, 1999) "The Green Skyscraper: The Basis for Designing Sustainable Intensive Buildings"

The study indicated that the use of passive systems to create a more comfortable indoor environment through bioclimatic design and how it deals with passive energy design, natural climatic forces, and local conditions to achieve comfort for building users by: (reducing the high temperature, entering solar radiation through the envelope Exterior, creating natural ventilation to achieve comfort through techniques used by designing facades, solar control, hanging gardens, using wind and natural ventilation, and other techniques for passive cooling purposes (such as fountains, or investing in the ground... etc.).

4.4 (Norman Foster, 2000) "Analog and Digital Ecology"

The study indicates reliance on natural energy sources, through modern intellectual trends based on the principles of ecology, using passive systems in architecture that consume less energy and produce less pollutants, and thus reflect the basic principles on which traditional architecture relied on the economic, climatic, and most importantly, social levels. Cultural, pointing out that architecture must create its own energy, and this is done by achieving integration between technologies, materials, and construction processes in building designs to reduce energy use and achieve a sustainable built environment. The study adopts a technological orientation to achieve sustainability, as most buildings appeared responsive to functional factors. The local climate and culture are within the site’s parameters, increasing natural lighting and ventilation and making the most of other natural energies to achieve a sustainable building. So that architecture becomes integrated at the urban level through compatibility with the context and surrounding environment at the ecological level through the adoption of passive systems, and at the technological level to achieve a design with high performance and energy efficiency.

4.5 (Magnoli Gian , 2001) "Design a DNA for responsive architecture."

The study indicates that the ecological ecosystem is characterized by permanence and continuity, as the structural systems that it consists of continue to function even if an element stops or is destroyed, unlike traditional linear systems that are not characterized by continuity and permanence, as the system collapses if an element in it collapses. Therefore, the study showed that structural architecture that mimics the organic structural system is more efficient and sustainable. The study pointed to examples of modular generation forms and open structure forms that resemble organic structural systems and are characterized by flexibility and adaptation to the changing needs of users and their effectiveness within the influences of the climatic environment. Organic forms are distinguished by their ability to respond to the environment similar To respond to the natural form at the design level as a whole, in the ability to grow and flow like the ability of organic form, and at the building level, the building envelopes, especially the roofs, took curved and flowing shapes similar to the covers of living crustaceans, and with kinetic performance to respond to the effects of temperature and solar radiation and create appropriate ventilation to create an environmental balance. Internal: The study referred to social wealth as the most crucial wealth that human existence can explore, as it refers to the connections and behavior that constitute the quality and quantity of a society's social interactions. Social wealth is the actual structure of society, while the built environment represents the natural structure that society can develop.

4.6. (Giles, Harry, 2003) " Structural Hierarchy "

The study revealed that natural forms share a similar structural system, with a focus on distributing forces and withstanding loads. However, there are variations in their external appearance. This is because natural structures possess a structural sequence and a gradient characteristic, which are commonly found in nature. These features have proven to be effective in adapting to and enduring environmental conditions and loads over time. As a result, natural forms exhibit different shapes and structures based on the specific functions of each organism. The structures are designed to support and connect with the surrounding materials. These principles can be applied in architecture, utilizing flexible membranes, suspended systems, crustaceans, pre-voltage systems, and other mechanisms that mimic the behavior of natural structures. Table 1 shows Summary of the theoretical framework of the aspects and dimensions of biomimicry in architecture.

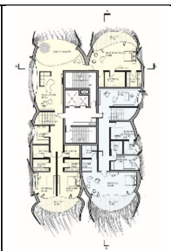
Table1. The theoretical framework of the biomimetic in Architecture

<table>
<tr><th>No.</th><th>Key Vocabulary</th><th>Secondary Vocabulary</th><th>Possible values</th></tr>
<tr><td>1</td><td>Definition of the biomimetic strategy</td><td>It is the process of creating a new type of architecture by combining biological specialization with architecture through technology and advanced materials, where the design process conveys the ideas of living nature and translates them as systematic steps of the design process</td><td></td></tr>
<tr><td rowspan="6">2</td><td rowspan="6">Sustainability aspects achieved through the biomimetic strategy</td><td>Harmony and harmony with the surroundings</td><td></td></tr>
<tr><td rowspan="3">Energy efficiency</td><td>Energy efficiency</td></tr>
<tr><td>Energy saving efficiency</td></tr>
<tr><td>Energy generation efficiency</td></tr>
<tr><td>Efficiency of performance and operation</td><td></td></tr>
<tr><td>Achieving environmental efficiency</td><td></td></tr>
<tr><td rowspan="7">3</td><td rowspan="7">Analysis level</td><td rowspan="2">Analyze the selection natural system</td><td>Direct metaphor</td></tr>
<tr><td>Indirect metaphor</td></tr>
<tr><td rowspan="2">Analyze the site and environmental impacts</td><td>Inconsistency with the site</td></tr>
<tr><td>Harmony and coherence with the site</td></tr>
<tr><td rowspan="3">Analyze the functions of the building</td><td>Level of openness</td></tr>
<tr><td>Level of Privacy</td></tr>
<tr><td>Responding to the idea of living architecture</td></tr>
<tr><td rowspan="13">4</td><td rowspan="13">Derivation level of the chosen natural system (model generation)</td><td rowspan="4">Form and morphology level</td><td>Level of the organism's form</td></tr>
<tr><td>Material Level</td></tr>
<tr><td>Structure Level</td></tr>
<tr><td>Cover Level</td></tr>
<tr><td rowspan="8">Behavior</td><td>Self-healing</td></tr>
<tr><td>Regulation and transfer of temperature</td></tr>
<tr><td>Water storage</td></tr>
<tr><td>Energy storage</td></tr>
<tr><td>Air transport</td></tr>
<tr><td>Regulating light exchange</td></tr>
<tr><td>Gas exchange</td></tr>
<tr><td>Absorption of pollutants</td></tr>
<tr><td>Ecosystems</td><td>Material (recycled to convert the energy)</td></tr>
</table>

			Structure and architecture of the system
			Geometric arrangement of the system
			Local materials within the site or place
			Relationships between buildings themselves within the site
5	Mechanisms for biomimicry	Adopting the simulation of living nature models in the composition of the structure	
		Adopting the simulation of the creation systems of living nature	
		Deriving and generating structures from biological installations	
		Adoption of formal metaphor from living organisms	
		Adoption of formal simulations	
		Direct formal imitation	
		Adoption of Adaptive Formal Living Systems Mechanisms	
		Formal harmony between the built environment and nature	
		External Terminations	
		Internal Terminations	
		Outer shell	
		Materials included in architectural elements	
		Materials included in the structural structure	
		Topographic site simulation	
6	Biomimetic features	Flexibility	
		Sustainability	
		Integration of shape with constructor function	
		Power bearing efficiency and load distribution	
		Dynamism	
		Flowability	

5 Practical Study

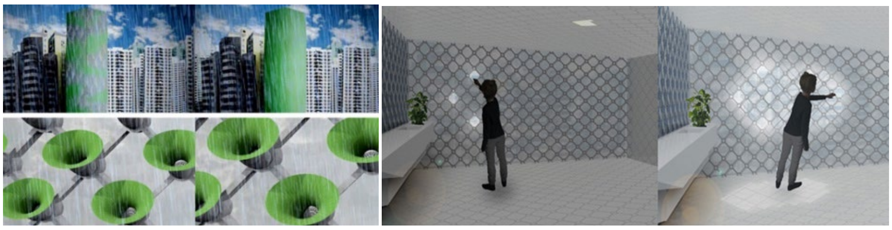
This paragraph represents the third procedural step related to the analysis of contemporary applied projects, as the study intended to select two projects. These projects were selected depending on their uniqueness and contextual diversity.

(Form 1: analysis of the researcher according to the theoretical framework) / Source: ArchDaily | Broadcasting Architecture Worldwide First Project / Housing tower/ B+U's Housing Tower Rethinks Window DNA , Lima, Peru, 2013	
Project outline and photos	  

<table>
<tr><td rowspan="23">Approach to

BIOMIMETIC</td><td>Definition</td><td colspan="2">The conceptual framework of design originated from the ability of architecture to exist between nature and technology, inspired by natural patterns, movements, and colors with the goal of creating an interactive and intelligent object construction.</td></tr>
<tr><td rowspan="3">Sustainability aspects achieved through the biomimetic strategy biomimetic</td><td colspan="2">Adapting to the surrounding environment</td></tr>
<tr><td colspan="2">Efficient performance and operation</td></tr>
<tr><td colspan="2">Energy efficiency</td></tr>
<tr><td rowspan="3">Analysis level</td><td colspan="2">Natural system: natural patterns, rethinking and designing DNA and applying it to the pattern of multi-story housing.</td></tr>
<tr><td colspan="2">Site analysis: embodying the beauty of the project through contradiction, imbalance and distortion with the site instead of homogeneity and softness.

Environmental effects: Vents operate as separators between indoor and outdoor, responding to environmental forces such as sun and wind. And exploiting potential active exchanges between natural and built environments.</td></tr>
<tr><td colspan="2">Analysis of the functions of the building: The exterior of the building is a direct result of the interior spaces and their relationship to specific points in the city The clear edge of the building is in a state of constant change instead of marginality and inertia The dining space with large folding glass walls can be opened to create an outdoor living experience with a rooftop penthouse with a large swimming pool and a shared garden for residents.</td></tr>
<tr><td rowspan="10">The level of derivation of the chosen natural system</td><td rowspan="4">Level of shape and morphology</td><td>The shape of the organism is inspired by the adaptation of the outer shell or skin to the surrounding conditions.</td></tr>
<tr><td>The material that makes it is advanced silicon compounds that blend the properties of materials at the molecular level and is capable of self-moving and nature simulating systems.</td></tr>
<tr><td>Structure and its parts: The exterior of the building is a direct result of the interior spaces and their relationship to specific points in the city, with linear additions along the window frames that create a smooth edge of the building, where they are not a single sharp and traditional state, rather a state of constant change.</td></tr>
<tr><td>The cover has been transformed into a thin film with gaps that mimics the pores of the shell and skin of living organisms.</td></tr>
<tr><td>Behavior</td><td>Functions: Temperature regulation and transmission – Air transfer – light exchange regulation – Gas exchange – Pollutant absorption.</td></tr>
<tr><td rowspan="5">Ecosystems</td><td>Material: Advanced silicon composite materials mixed the properties of materials at the molecular level, which helped reduce gas emissions in buildings and instead became closer to the performance of adaptable organisms.</td></tr>
<tr><td>The structure and format of the system is a site-cast concrete panel system that contrasts the modified physical properties of the concrete shell, with the openings of the LED transparent articulated fiberglass composite to give the tower a glow at night.</td></tr>
<tr><td>Geometric arrangement of the system</td></tr>
<tr><td>Local materials within the site or place: Approval of physically modified materials</td></tr>
<tr><td>The relationships between the buildings themselves within the site: the project embodied contradiction, imbalance, and distortion within the site instead of homogeneity and softness. The moving foci helps to redefine the built environment due to the effect of the adaptive living building.</td></tr>
<tr><td rowspan="3">Mechanisms for biomimicry</td><td colspan="2">Adoption of adaptive morphological living systems mechanisms</td></tr>
<tr><td colspan="2">Outer shell</td></tr>
<tr><td colspan="2">Materials included in the structural structure</td></tr>
<tr><td rowspan="3">Biomimetic features</td><td colspan="2">Flexibility</td></tr>
<tr><td colspan="2">Dynamism</td></tr>
<tr><td colspan="2">Integration of form with the original function</td></tr>
</table>

(Form 2: analysis of the researcher due ot the theoretical framework) / Source: [Page not found « (inhabitat.com)] Second Project / Habitat Building in China Multi-Storey 2020			
Project planning and photos			
Approach of BIOMIMETIC	Sustainability aspects achieved through the biomimetic strategy biomimetic	Harmony and coherence with the surroundings	
		Energy generation efficiency	
		Achieving environmental efficiency	
	Analysis level	Taking inspiration from natural systems, represented by the mechanism of action, the shape of the skin and its pores, the outer layer of the plant and its stomata, and simulating the breathing process of a living organism. The approach is inspired by nature to live in a city whose urban landscape and ecosystem appear constantly vibrant and evolving. This project is an example of biomimetic architecture due to the valves that express high-tech ideas and basic cellular functions to create future living structures, that function like natural organisms.	
		Site Analysis and Environmental Impacts: Adopting the ecosystem as a design system and redefining the concept of outdoor spaces.	
		Function analysis: The building responds to the thought of living architecture at the level of movement, breathing and water handling, while the windows were built on the basis of opening and closing according to the quantities of CO2 gas, not complex and without huge mechanisms, also, they are an integral part of SMA wires in flexible transparent plastic.	
	The level of derivation of the chosen natural system	Level of from and morphology	Organism shape: alive human skin and stomata of the outer plant shell.
			Material: An inert material system was used for construction and protection. As for the skin, it is a living membrane that achieves a connection between the inside and the outside. It contains many stomata and cellular openings that participate in the gaseous exchange in a process similar to the process of transpiration in plants. And the use of graphene oxide material, which responds to small changes in humidity and temperature in the artificial stomatal layer.
			The structure and its parts: The structure represents a shift towards making it alive and functioning like natural beings, the building has elements that open, close, breathe, and adapt according to their environment.
			The cover: Transforming it into a living thin film to allow exchanges and interactions with the surrounding space.
		Behavior	Functions, processes and behaviors: temperature regulation and transfer – water storage and recycling – energy storage – conversion of energy into electricity – air transfer – light entry.
		Ecosystems	Material: The outer shell of the building converts the waste produced into biogas energy, which can be released for various uses in the environment. In addition to recycling rainwater and absorbed moisture and using it in different forms.
			Structure and system structure: The structure is coated with living material, with an emphasis on the complementarity of water storage and electrical systems that is supplied with. Along with the inability to replace the outer shell and keep maintenance works only.
			The used materials represent a change to the concepts of traditional construction and the

			surface and structure. They are considered as living future materials as they respond to the local environmental specificity, where the gaps represented by openings are a smart flexible metal that expands and responds to external changing environmental conditions.
			Relationships within the site : The design of the building is an exploration of the relationship between advanced technology and biochemistry in architectural facades, which can respond to the demand for sustainable living in dense urban areas. as well as the fact that the building is responsive to local conditions due to the openness and closure of the structures in the façade.
	Mechanisms for biomimicry	Adoption of mechanisms of adaptive morphological living systems	
		Exterior Finishes	
		Interior Finishes	
		Exterior cover (shell)	
		Materials included in the structural structure	
	Biomimetic simulation features	Integration of form with original function	
		Dynamism	

6 Application Results

Complementing what was mentioned in the practical study, this paragraph applies the theoretical framework to the selected projects. Table 2 shows the reflection of the application in the selected projects.

Table 2. Application of the theoretical framework of biomimetics in Architecture to the selected projects.

No.	Key Vocabulary	Secondary Vocabulary	Possible values	1	2
.1	Definition of the biomimetic strategy Sustainability aspects achieved through the biomimetic strategy.	Harmony and harmony with the surroundings			
		Energy efficiency	Energy use efficiency		
			Energy saving efficiency		
			Energy generation efficiency		
		Efficiency of performance and operation			
		Achieving environmental efficiency			
.2	Analysis level	The selected natural system	Direct metaphor		
			Indirect metaphor		
		Analyze the site and environmental impacts	Inconsistency with the site		
			Harmony and coherence with the site		
		Analyze the functions of the building	Level of openness		
			Level of Privacy		
			Responding to the idea of living architecture		
.3	Derivation level of the chosen natural system (model generation)	Form and morphology level	Level of the organism's form		
			Material Level		
			Structure Level		
			Cover Level		
		Behavior	Self-healing		
			Regulation and transfer of temperature		
			Water storage		
			Energy storage		
			Air transport		
			Regulating light exchange		
			Gas exchange		
			Absorption of pollutants		
		Ecosystems	Material (recycled to convert the energy)		
			Structure and architecture of the system		
			Geometric arrangement of the system		
			Local materials within the site or place		
			Relationships between buildings themselves within the site		

.4	Mechanisms for biomimicry	Adopting the simulation of living nature models in the composition of the structure		
		Adopting the simulation of systems that create living nature		
		Deriving and generating structures from biological facility		
		Adoption of formal metaphor from living organisms		
		Adoption of formal simulations		
		Direct formal imitation		
		Adoption of Adaptive Formal Living Systems Mechanisms		
		Formal harmony between the built environment and nature		
		External Terminations		
		Internal Terminations		
		Outer shell		
		Materials included in architectural elements		
		Materials included in the structural structure		
		Topographic site simulation		
.5	Biomimetic features	Flexibility		
		Sustainability		
		Integration of the shape with the created function		
		Power bearing efficiency and load distribution		
		Dynamism		
		Streamline		

7 Results

The application of the theoretical framework to the selected samples has yielded several significant findings:

Biological simulation in architecture has demonstrated its potential in achieving sustainability, leading to improved efficiency, adaptation, and continuity. By emulating natural processes and systems, architects can design buildings that are environmentally friendly and energy efficient. Effective integration of natural systems and technology is crucial. Rather than considering technology as separate from nature, it should be viewed as a tool to enhance natural systems for architecture. This integration can make architectural designs more efficient and compatible with development requirements. Biomimicry architecture represents a synthesis of principles and ideas from various approaches to sustainable environmental design. By drawing inspiration from nature, architects can create built environments that are not only aesthetically pleasing but also promote sustainability and environmental harmony. Contemporary and future architecture should prioritize incorporating biological principles into design. By embracing biomimicry and understanding adaptation strategies found in nature, architects can create buildings that effectively respond to environmental changes and optimize resource use. Morphological adaptation, which involves changes in shape or size, is the most common form of adaptation observed. It is often followed by physiological adaptation that is influenced by the properties of the materials used in construction. These two forms of adaptation can occur individually or together, with the properties of the material influencing the external form. Application of principles and classifications may vary in each construction project. The decision on which principles to apply depends on the specific inspiring element and the chosen simulation methods, levels and dimensions. However, all architectural models need to take into account the principles of the surrounding environment and take into account site conditions and climatic changes. Mimicry of physical or mechanical nature is more effective for achieving adaptation, while biomimicry is more suitable for imitating the behavior of an organism or simulating the properties of materials.

Biological simulation is not limited to a single level or dimension. Combining multiple levels and dimensions in one model can lead to more efficient adaptation of buildings to their surrounding climate and environment. Sustainable organic forms are designed to withstand various natural conditions, including heavy rains, hurricanes, floods, fires, earthquakes, and soil compaction. Biomimicry of organic forms prioritizes integration with the surrounding context and topography of the site. Designers focus on utilizing solar energy, water, and wind as sources of energy to conserve energy and achieve thermal gain, insulation, ventilation, and water circulation. By incorporating natural configurations, systems, and technology, designers can identify and adapt these concepts to the natural environment. Advanced technology can support and enhance natural systems, creating a cohesive design that connects nature, culture, and technology. Nature provides a wealth of systems, elements and resources that can be utilized in architecture. The integration of these structures, materials and systems allows for a balanced and harmonious design. Bioclimatic design plays an essential role in achieving sustainability by relying on passive systems to create a comfortable indoor environment for building users. Natural forms and their structural systems have proven their efficiency over time in withstanding environmental conditions and resisting loads. While the external appearance may differ, the distribution of forces in the structural system and resistance to loads are similar. The harmony exhibited by natural organic structures, resulting from the integration of form with structural function, can be used in architectural forms and structures. Overall, these results demonstrate the potential of biomimicry and the importance of incorporating natural principles into architectural design to achieve sustainability, efficiency, and adaptability in the built environment.

8 Conclusion

The application of the theoretical framework to the selected samples showed the following results:

1. This study explored the potential of biomimicry as a strategy for achieving sustainability in architectural design.
2. The research concluded that the principles of environmental sustainability are inherently present in natural organisms and ecosystems. As such, biomimicry provides an effective methodology for developing sustainable architectural solutions by emulating these successful natural models.
3. Adopting a biomimetic approach can enhance efficiency, continuity, adaptation and integration with the surrounding environment in building design.
4. The study also revealed different methods, levels and dimensions that can be implemented when translating biological measurements into architectural contexts. This includes directly mimicking entire organisms or specific features, adopting natural building techniques or material properties, and replicating ecosystem relationships.
5. The combined application of multiple simulation strategies allows the creation of a more responsive and optimized sustainable architecture. Overall, biomimicry represents an innovative design trend that integrates biological and architectural knowledge.
6. As architects increase their understanding of the adaptive natural world, they can create built environments that enhance the environment, conserve resources, withstand climate challenges, and meet human needs.
7. Ultimately, fostering collaboration between architects, biologists, engineers and other professionals will be key to fully unleashing the potential of sustainable, nature-inspired architecture.

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