

# **Applying innovative criteria to achieve Biomimicry in Architecture**

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## **Abstract:**

Since creation began, human beings was surrounded by nature and it's the main teacher and guide for us in many parts of life, including the field of architecture, as simulating nature that means (Biomimicry) is using innovative methods to reach sustainable buildings, it's a new science that investigates nature's greatest idea. The main objective of this paper is to abstract a set of the best standards for simulating nature to have a specific model that can be followed to reach an innovative, sustainable building that adapts to different conditions and evolve to survive and knowing the impact of these criteria to the building efficiency through presenting an international and local case-studies and applying biomimicry criteria on them then making a questionnaire to a group of specialists. and applying them to create creative and sustainable solutions for industry and research.

## **keywords:**

Biomimetic Architecture, Sustainable building, Innovative Architecture, Nature principles, Energy efficiency, Bio-inspired design, Building technology.

## **1- Introduction**

Biomimicry is the study of nature, including its principles, directions, laws, methods, processes, and details, to mimic or take inspiration from it to solve human problems. It can also educate us about systems, elements, structures, and aesthetics. By delving deeper into how nature handles today's problems, we may be able to find more timely solutions and explore new avenues for our built surroundings. (1)

There is a huge difference between biomimicry and biomimetics as biomimetics means copying the action or presence of someone or something else but biomimicry means imitating or taking inspiration from nature. (2)

The research discusses the history of simulating nature from where and when it began and presents a set of criteria and standards of nature and also presents iconic international and local analytical examples and the application of these criteria on them.

We also have to clarify the relationship between simulating nature and aesthetic inspiration as the application of the standards of nature such as the use of solar panels, recycling water, natural ventilation, daylight, and local materials that reduce energy consumption and increase building efficiency

## **2- Problem Statement:**

The problem here is that there are shortcomings in the way of applying the standards for simulating nature, as there are many standards for simulation, if they are applied to the building truly, we will reach innovative buildings, but the gap here is in the absence of the correct method of application as there is no specific and clear way to be taken and applied on the building.

## **3- Research aim**

The major goal is to come up with a set of standards inspired by nature and apply them to the building to solve human issues and create a more evolved structure that responds to the changing situation.

## **4- Research hypothesis**

There's a set of iconic international and local case studies that will be analyzed and applied nature's principles to them and a set of criteria that have been carefully selected by a group of architects through the questionnaire to reach the best-required standards that can be followed to reach innovation.

## **5- Research Methods**

The research depends on several main points which are, **Firstly** the theoretical part that Presents definitions of Biomimicry, its history, dimensions, and its impact on architecture. **Secondly**, the Analytical part, in this part of the research, some criteria will be followed to derive the results of the study. These criteria were presented to a group of specialists by conducting a questionnaire to reach the best of them.

A study of iconic international and local case studies that simulate nature and its principles, then extracting criteria that must be applied to the building to achieve the desired goal, which is innovation in the building and adapting to different conditions and developing to survive **Thirdly**, the practical part, By making a general questionnaire and knowing the importance of each criteria in Biomimicry to extract a set of Standards if applied to the building, we will reach a sustainable building that adapts to different conditions and develops to survive.

### **First, The theoretical part**

There is a specific problem, which is the absence of the correct way to apply the standards to the different architectural buildings. Therefore, the different architectural criteria were presented to a group of specialists, and the best of them were selected through the questionnaire.

As the solution to this problem has not been presented before when the author Rajshekhar, Roa presented in his paper the shortage in architectural buildings and solved it using methods inspired by nature, whether in forms, such as taking the external art of natural structures such as trees, plants and the process such as collecting and storing rain and converting sunlight into energy.

Also, in the research presented by the author Dr .Gehan&Arch Nouran Osama, it was shown that there are shortcomings in the way of saving energy and applying it to buildings, rationalizing the use of energy, and achieving comfort inside the building by applying biomimicry principles.

### 1- Biomimicry Definition.

Biomimicry is The study of nature, its models, systems, processes, and aspects that may be copied or driven to address, The words biomimicry and biomimetics are derived from Greek. It's a sustainable invention that embodies high-performance and resource-efficient design solutions. (3)

It's a new science that investigates nature's greatest ideas and then imitates them to create creative and sustainable solutions for industry and research. (4).

The term (Biomimetic) is Copying the actions or presence of someone or something else.

Figure (1) shows nature's pattern, shapes, form, behavior, and strategy.



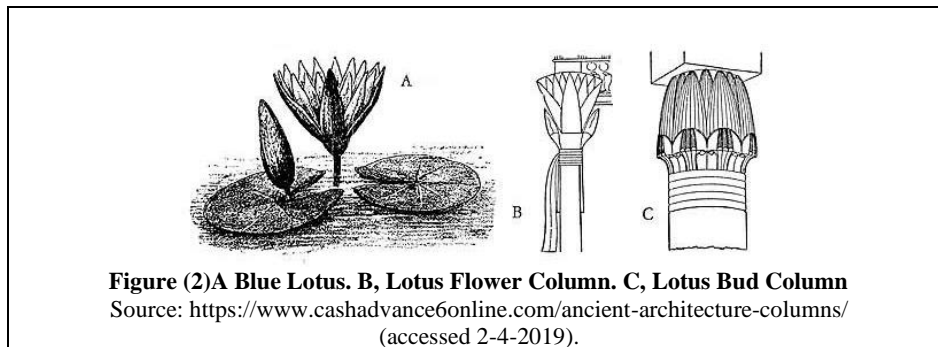
### 2- Historical background of Biomimicry.

The history of Biomimicry goes back to 500 B.C, the Greek philosophers have seen natural organisms as models for a harmonious balance and proportion between the parts of a design that is synonymous with the classical ideal of beauty. (5)

Architects have been employing nature mimicking from ancient times, since it is an old science, not a new one, as they watched animals and their behavior in shelter and survival situations. (6)

The term "biomimicry" was popularised by Janine Benyus, a scientist and author who pioneered an innovative approach to design that uses nature as a source of inspiration to tackle any design problem. In her book named “Biomimicry: Innovation inspired by nature” published in 1997, she defined the Biomimicry idea as ”a new science which studies nature as a model and an inspiration from which one can imitate its design and process to solve human problems”.(7)

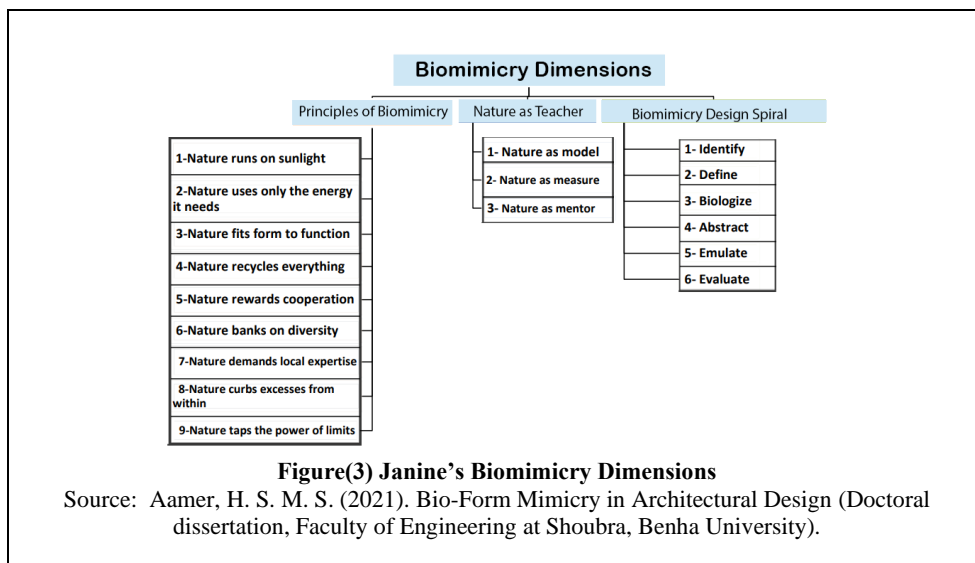
The ancient Egyptians were the most prevalent naturalists, taking inspiration from palms, lotuses, and papyrus plants. The hieroglyphs (Egyptian alphabet) sometimes mimicked natural shapes, such as a bird's feather or the outline of a whole animal.



### 1- Biomimicry Criteria.

Nature has several criteria and dimensions that it uses to survive and adapt to different conditions. If these principles are taken and applied to buildings, we will reach a successful building that is sustainable and also environmentally friendly. The biomimicry criteria and dimensions are :

**-First:** Approaches to Biomimicry are divided into two dimensions (problem-based, and solution-based approaches). (8)



**-Third;** Innovation principles (Analysis, Research Knowledge, Simplicity, smallness, leadership). (11)

**-Fourth;** levels of Biomimicry (Organism, Behavior, Ecosystem). (12)

### 3- Biomimicry in Architecture

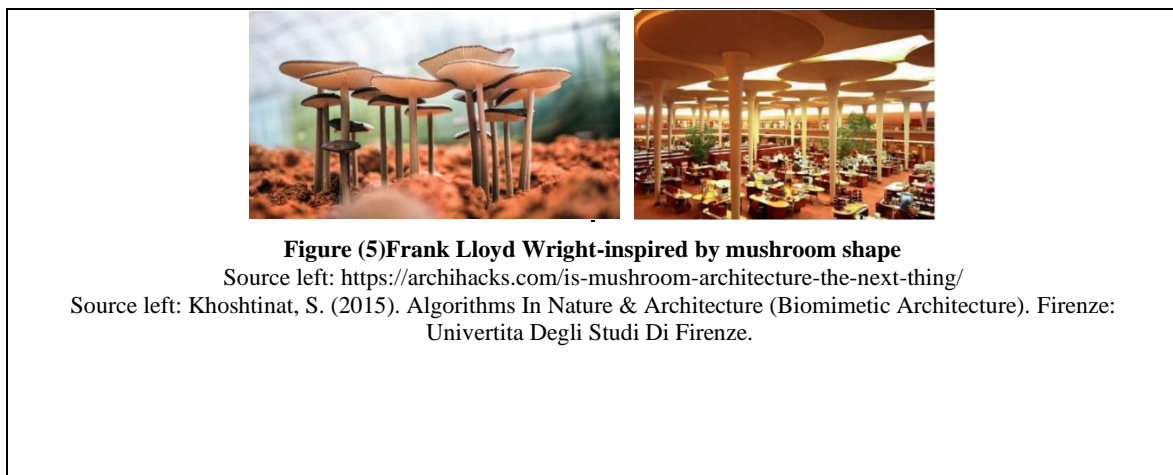
Many architectural buildings use the simulation principle; architects such as Santiago Calatrava, Norman Foster, Michael Pawlyn, Moshie Safdie, and Frank Lloyd Wright used Biomimicry as the main guide to applying it to their projects, to achieve building sustainability and adjustment to changing environmental factors, as the integration of technological developments with nature gave the architecture a new direction that maintains the balance of the environment. (13)

There are several examples of how this has resulted in great works of architecture, such as:

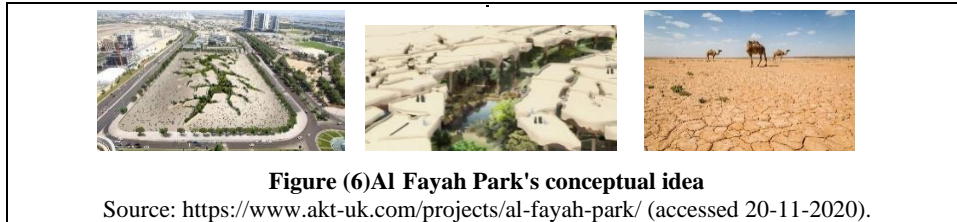
The Gherkin is shaped like a venus flower Basket sponge, with a circular shape that helps spread pressures in different directions and decreases tensions caused by strong water currents, The role of using biomimicry in Architecture here is using nature's shape and process. (14)



Buildings like Frank Lloyd Wright's Johnson Wax building, with its mushroom-inspired thin-shell concrete and steel-mesh columns, begin to explore the potential of biomimicry's architectural product. The role of using biomimicry in Architecture here is to use nature's shape and structure (15)



The Al Fayah Park in Abu Dhabi's Desert imitates the form of desert terrain. experimenting with the notion of constructing a building out of the shattered desert crust The role of using biomimicry in Architecture here is using nature's shape. (16)



After studying the theoretical part of the research and identifying the simulation of nature, its definition, criteria, and its impact on architecture, then these principles and criteria will be applied to an analytical example.

## Secondly, The Analytical part




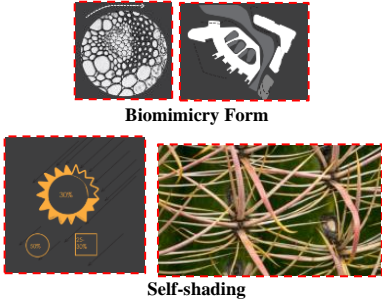
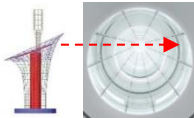

Based on the "theoretical study "Through which it was possible to identify Biomimicry, its criteria, and its impact on architectural buildings.






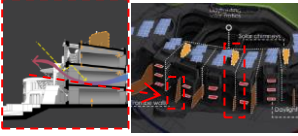



International case studies have been analyzed to know the impact of the application on the success of the building and achieving its main goal of it, which is innovation, adapting to different conditions, and evolving to survive.

The case studies selected by the researcher are based on the following criteria:

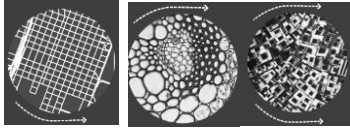


- The building design is based on simulating nature and using the principles of biomimicry.
- The building must be newly built.
- The building has multiple uses.




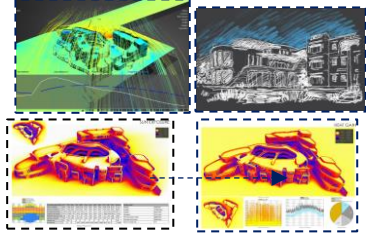
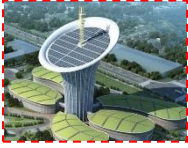

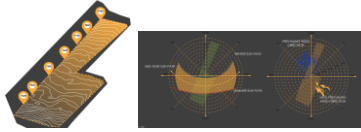

Table (1) presents an international case study (Wuhan New Energy) and a local case study (Natrunia Silver Lodge).


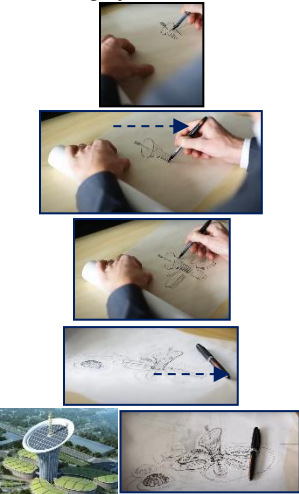

<p><b>Project Name: Wuhan New Energy Center</b>  <b>Designer: Grontmij and Soeters Van Eldonk</b>  <b>Location: Wuhan, China</b>  <b>Construction started:2012</b></p> 		<p><b>Project Name: Natrunia Silver Lodge</b>  <b>Designer: S-Cube</b>  <b>Architects(Dr. Safi eldin&amp;Eng.Shady Yossef)</b>  <b>Location: Wadi El-Natroun, BEHIYRA, Egypt.</b>  <b>Completion Date:2020.</b></p> 		
Approaches to Biomimicry	Problem-Based	Direct	<p><b>Direct formation (Flower shape inspiration)</b></p> <ul style="list-style-type: none"> <li>•The Calla Lily flower is the inspiration behind the design, therefore it is also called the Energy Flower) the project, Architects who picked flowers as their design created a unique and amazing architectural project.</li> <li>•The project was designed to look like a lily, with a central tower surrounded by lower towers shaped like flowers. (17)</li> </ul>  <p><b>Wuhan New Energy concept</b>  <a href="https://www.juliasflorist.com/blog/flower-inspired-architecture-results-in-stunning-buildings/">https://www.juliasflorist.com/blog/flower-inspired-architecture-results-in-stunning-buildings/</a>                  (accessed 16-1-2022)</p>	<p><b>Indirect (self-shading strategy-Biomimicry patterns)(18)</b></p> <ul style="list-style-type: none"> <li>•Bio Mimicking in the present work shall be on shaping, functionality, and integration of environmental systems of cactus.</li> </ul>  <p><b>Biomimicry Form</b></p> <p><b>Self-shading</b></p>
	Solution-Based	Indirect	<p><b>Aluminum tube system (Allows natural ventilation &amp; daylight)</b></p> <p>Aluminum panels run vertically through the steel tower allowing air to be sucked through the structure and window openings while hot air rises the central shaft, helping to ventilate space and cool occupants. (19)</p> 	<p><b>Local eco materials</b></p> <p>The building used adobe bricks and native desert clay walls.</p>  <p><b>Local Ecological materials used in Natrunia silver Lodge</b>                  NATRUNIA SILVER LODGE-219.pdf</p>
The major principles of Biomimicry		Resource material		




		<p style="text-align: center;">Energy Efficient</p> <p><b>Shades</b>                  •Use façade blinds to reduce the demand for air conditioning &amp; allowing daylight.</p> <p><b>Natural daylight</b>                  •The center tube, allows daylight to enter the windowless interior, reducing the need for illumination.</p> <p><b>Solar panels</b>                  •The electricity created by the PVs power the building</p>   <p>The Energy Flower is tilted towards the sun to maximize the performance of the 3,500m<sup>2</sup> photovoltaic arrays</p> <p><b>Optical illumination system (20)</b>                  The optical illumination system reaches from the underground area to the grass ground's surface. that can supply lighting for the entire subterranean park using</p>  <p style="text-align: center;"><b>Optical illumination system</b></p>	<p><b>Courtyard design</b>                  Implementing a Courtyard designed to allow natural cross-ventilation.</p>  <p><b>Roof solar panel</b>                  Solar panels serve two purposes: one is to generate electricity, and the other is to operate as double roofing, reducing direct heat gain by 50% from the roof into the inside environment, ensuring user comfort.</p>  <p><b>Daylighting shelves</b>                  •A light shelf is a horizontal surface that reflects sunlight throughout a building. Light shelves with high-reflectance upper surfaces are situated above eye level, which reflects daylight onto the ceiling and deeper into the space.</p>  <p style="text-align: center;"><b>Extending Daylight in internal spaces without glare</b></p> <p><b>Daylighting solar optics</b>                  •Providing 6 hours of daylighting to inside spaces to reduce electricity use.</p>  <p style="text-align: center;"><b>Daylighting solar optics</b></p>
	<p style="text-align: center;">Evolve to survive</p>	<p>•Zero carbon emissions, Energy natural passive.</p>	<p><b>Reviving of lake</b>                  •Rehabilitation of existing lake and uplifting its performance.</p> 
	<p style="text-align: center;">Adapt to changing conditions</p>	<p><b>Climate adaptation</b>                  By using shades that cool the internal spaces.</p>	<p><b>Trombe wall eco-material</b>                  •The Trombe wall idea increases the flow of ventilation by using high thermal mass walls that react to all environmental variables.</p>  <p style="text-align: center;"><b>Eco material</b></p>



	Nature as a teacher	Model	-	<p><b>Model</b></p> <ul style="list-style-type: none"> <li>•Simulating Biomimicry patterns, shape, and cactus strategy</li> </ul>  <p><b>Modular, Vernacular, Biomimicry form</b></p>
		Measure	<p>The building applied some of nature’s strategies and laws as follows:</p> <ul style="list-style-type: none"> <li>• Applying the <b>1<sup>st</sup> principle (Nature runs on sunlight)</b> by reaching zero carbon emission.</li> <li>•Applying the <b>2<sup>nd</sup> principle (Nature uses only the energy it needs)</b> by using wind turbines to generate electricity, also using solar panels on the roof to use for heating water and generating renewable electricity.</li> <li>•Applying the <b>4<sup>th</sup> principle (Nature recycles everything)</b> by collecting the rainwater in the bowl fixed on the roof to supply all levels with it.</li> </ul>	<p><b>The building applied some of nature’s principles which are:</b></p> <ul style="list-style-type: none"> <li>•The <b>1<sup>st</sup> principle: (nature runs on sunlight)</b> Using the Atrium as natural ventilation helps to eliminate the problem of pollution and natural ventilation.</li> </ul>  <p><b>Atrium strategy</b></p> <ul style="list-style-type: none"> <li>•The <b>2<sup>nd</sup> principle (Nature uses only the energy it needs)</b> -By using the double glazed for facades to decrease the heat that enters the building.</li> <li><b>The 4<sup>th</sup> principle (Nature recycles everything)</b> By making treatment for gray water and using it for toilet flushing and irrigation this opportunity helped to decrease water consumption.</li> </ul>  <p><b>Gray water</b></p>
		Mentor	<p><b><u>Lily flower simulation</u></b></p> <ul style="list-style-type: none"> <li>•Nature is the source of inspiration by simulating the lily flower.</li> </ul>	<ul style="list-style-type: none"> <li>•The building followed nature in several principles by simulating its shape and its way to solve problems.</li> </ul>

	Biomimicry Design spiral	Identify		(A)The design starts with the identification of the surrounding environment,(B)After that translated the design into a conceptual sketch.
		Translate		(D)Developing the idea by applying nature principles, then evaluating the design by using several programs.
		Discover	<p>(A)The building simulates the lily flower form (B)translating this idea to a conceptual sketch, designers proposed several designs, however, it was not easy to work out a perfect design</p>	(E) evaluating the design by using several methods like programming, and modeling.
		Emulate		 <p style="text-align: center;"><b>Design spiral steps</b></p>
		Evaluate	 <p>(C) the design developed from an idea to a real design (D) calas lily design combining nature, technology, (E) art was finally selected, and evaluating if it follow nature principles.</p>	
Innovation Principles		Analysis	<ul style="list-style-type: none"> <li>The designer analyzed the city and decided to show that chain is moving toward a more sustainable future in which cities are powered by a force of nature rather than by fossil fuels.</li> </ul>  <p style="text-align: center;"><b>Lily flower</b></p>	<p><b>Contour and wind analysis</b></p> <ul style="list-style-type: none"> <li>The design starts with the environment, contour levels, and sun &amp; wind analysis to take the most of the benefits from it and study if this design will cause a better change.</li> </ul>  <p style="text-align: center;"><b>Contour and wind analysis</b></p>
		Research and Knowledge	<p>collecting data about user needs, and also about the climate of Wuhan considered one of the three furnaces in china with a temperature peaking at 45° c, this meant the design team had the enormity Challenge of creating a low-energy building in the city.</p>	<ul style="list-style-type: none"> <li>Ask and see innovators' similar works and decide what the design should be to add value to the building.</li> </ul>
		Simplicity	<p>By achieving sustainability in a simple way such as recycling rainwater, using solar panels for heating water, etc...</p>	<ul style="list-style-type: none"> <li>The building used simple ways that achieved comfort for humans and raised its efficiency, such as solar panels, recycling water, local materials, a fog Catcher, Atrium for natural ventilation.</li> </ul>  <p style="text-align: center;"><b>Principles that the building used</b></p>

		<p> Simplicity</p>	<p>By achieving sustainability in a simple way such as recycling rainwater, using solar panels for heating water, etc...</p>	<p>•The building used simple ways that achieved comfort for humans and raised its efficiency, such as solar panels, recycling water, local materials, a fog Catcher, Atrium for natural ventilation.</p>  <p><b>Principles that the building used</b></p>
		<p> Smallness</p>	<p><b>Starting with a small scale</b>                  •For sure any new idea starts on a small scale to study its efficiency before the next step, this is what was done in this project.</p>  <p><b>Small scale study</b></p>	<p>The Design starts with a small conceptual sketch .</p>
<p>Leadership</p>			<p>Zero carbon- sustainable building</p>	<p>•The building is highly probable to be the leader for the buildings that are located in the same environment with the same condition.</p>  <p><b>Innovation steps that the building followed</b></p>

Biomimicry Levels	Organism	Form	<p><b><u>Lily flower shape</u></b>                      •The building generates the external shape (Calla Lily) flower.</p>  <p>The building mimics the (Calla Lily) flower.</p>	<p><b><u>Biomimicry patterns</u></b>                      •Biomimicry plays an important role in shaping the ecological envelope. mimicking can be in 3 dimensions, shaping, function, and methodology. Bio Mimicking in the present work shall be on shaping.</p>  <p style="text-align: center;">Biomimicry shape</p>
		Material		
		Construction		
		Function	-	<p><b><u>Function</u></b>  <b><u>Cactus strategy</u></b>                      Mimicking functionality and integration of environmental systems of cactus.</p>  <p style="text-align: center;">Cactus strategy</p>
		Process	-	-
	Behavior	Form	-	-
		Material	-	-
		Construction	-	-
		Function	-	-
		Process	-	-

	Ecosystem	Form	-	-
		Material	-	-
		Function Construction	-	-
		Function	-	-
		Process	-	-

### The impact of using biomimicry in Architecture ?

Using nature's principles allows the designer to enhance the architectural building that is created as an outcome of existing environment materialization.

- Using nature's principles allows the building to reduce energy consumption and deal with local materials that help the building to develop and adapt to different conditions like climate adaptation.
- following innovation principles to achieve the main goal of the building which is creating an innovative and sustainable building.

### Thirdly: The Practical part

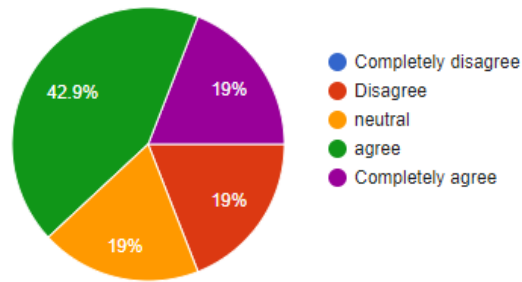
A questionnaire was made to a group of architects through (Google Forms) using a Likert scale asking architects about the importance of each criteria and its effect on the building, and its impact on achieving the goals of the building.

If these criteria are applied to the building, it will become an innovative building based on the application of simulating nature.

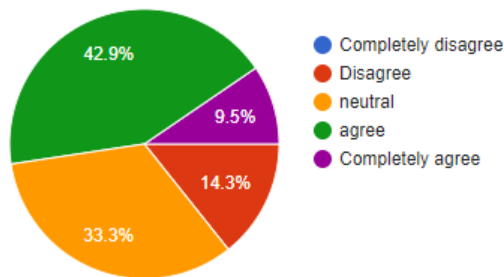
The questionnaire was made simply, and that was intended to facilitate the identification of the most important criteria and influence on the success of the building.

The questionnaire results are as follows :

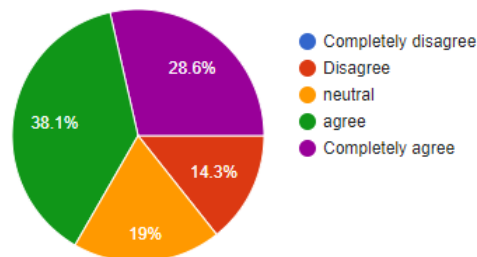
- Does this example follow the Problem-Based approach (Direct)? These criteria achieved 76% in the relative weight.



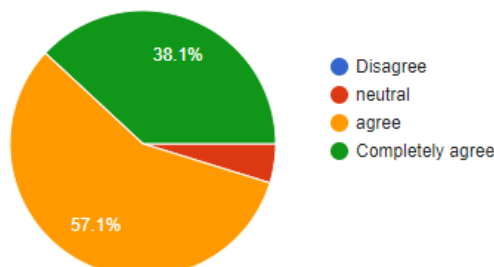
•Does this example follow the solution-Based approach (Indirect)? These criteria achieved 73% in the relative weight.



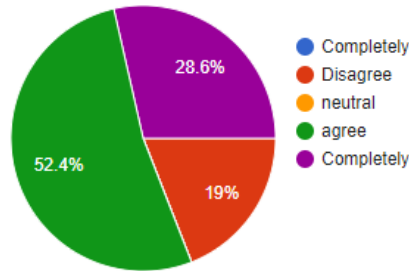
•Does this example follow the Resource material? These criteria achieved 80% in the relative weight.



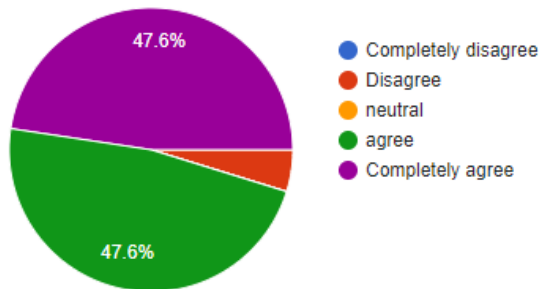
•Does this example follow Energy efficiency? These criteria achieved 91% in the relative weight.



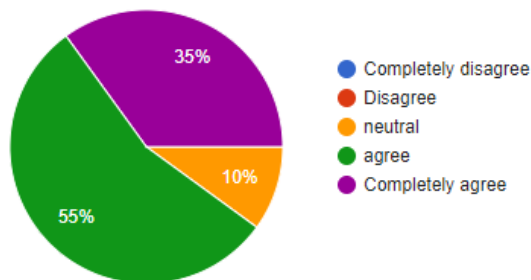
•Does this example follow the Evolve to survive? These criteria achieved 52% in the relative weight.



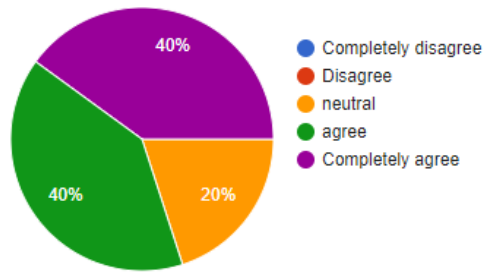
•Does this example follow the adapt to changing conditions? These criteria achieved 92% in the relative weight.



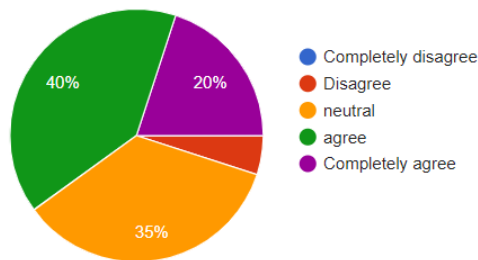
•Does this example follow Nature as a Teacher(model, measure, mentor)? These criteria achieved 69% in the relative weight.



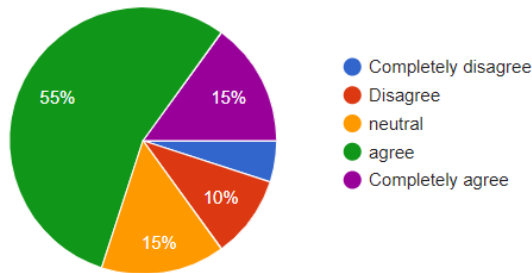
•Does this example follow Biomimicry Design Spiral(Identify, Translate, Discover, Emulate, Evaluate)? These criteria achieved 84% in the relative weight.



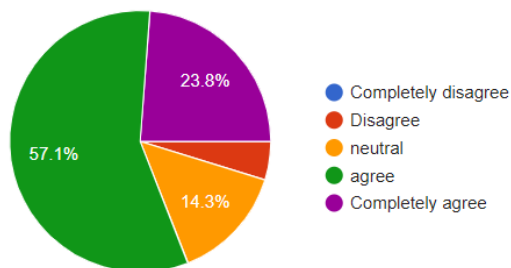
•Does this example follow (a)Analysis (b)Data collection (c)simplicity (d)smallness (e) leadership? These criteria achieved 55% in the relative weight.



•Does this example follow the Organism level? These criteria achieved 73% in the relative weight.

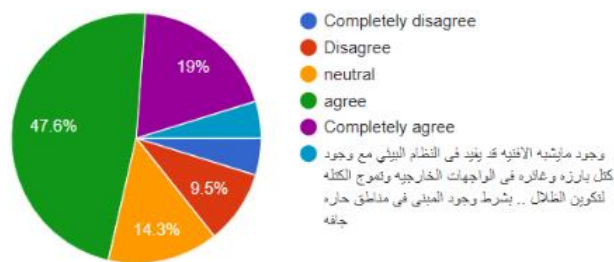


•Does this example follow the Behavior level? These criteria achieved 84% in the relative weight.



•Does this example follow the Ecosystem level? These criteria achieved 84% in the relative weight.





From the previous results, it is possible to deduce the most effective and influential criteria for the success of the building and its achievement of the required goals, which can be applied to other buildings to increase the efficiency of the building and achieve the desired goals.

## Results

Using a set of criteria to know the extent of their impact on the efficiency of the building and achieving the desired goal of innovation through the use of the principles and laws of nature. as the results of the analysis showed that all criteria are important and affect the building and its efficiency, but in different proportions, so it can be divided into six categories.

**First**, (a) The (problem-based) Approach criteria were successful as 76% in the relative weight, it succeed in dealing with nature's simulation. (b) The (solution-based) Approach criteria were successful as 73% in the relative weight, it succeed in dealing with simulating nature.

**Second**, (a) (Resource material) this criteria was successful as 80%, it succeed in dealing with the local material that is friendly to the environment. (b) (Energy Efficiency) criteria were successful in 91% as it deals with the whole system in the building that can reduce the energy consumption by using several ways like shades, solar panels, solar optics, etc. (c) Evolve to survive criteria succeed as 52% as the building develop to remain, but these criteria didn't affect the building system and neglecting the main target, therefore it has achieved a low success rate. (d) Adapt to changing conditions succeed in 92% by using different ways to adapt like climate adaptation. **Third**, Nature as a teacher achieved 69% as it deals with (model, measure, and mentor) by imitating nature its form, patterns, and Behavior, and using nature's principles. **Fourth**, the Biomimicry design spiral, succeed in achieving 84% by following several steps as simulating nature, translating this idea into a concept, proposing several designs developing the idea into a real design, and finally evaluating the design.

**Fifth**, Innovation this criteria achieved 55% in the relative weight as it starts with the environment analysis, asking users about their needs, using simple ways for simulating nature and talking about its principles, and finally aiming to leadership.

**Sixth**, Levels of Biomimicry

(a) Organism level criteria achieved 73% in the relative weight by simulating the shape of nature.

(b) Behavior level achieved 84% by simulating nature's performance.

(c)Ecosystem level achieved 84% by emulating how an organism interacts with the environment and how many parts work together.

## **Conclusion**

Nature is the best teacher, it can teach us about systems, materials, processes, structures, and aesthetics. Apart from measures to protect the environment through the rationalization of energy resources and the reduction of pollution.

Throughout history, human has dealt with nature directly, as it was part of architecture, man used caves to live in them and used natural materials for construction, as nature has many laws and principles if applied in the right way, we will solve human problems and reach sustainable buildings, decreasing its energy consumption and it adapts to the surrounding environment.

Finally, the questionnaire deduced the most effective criteria in the building that can affect its building efficiency and archive innovation, this questionnaire helped to extract a set of standards to create an iconic model that can be followed to reach sustainable buildings.

## **Recomendation**

Using the Biomimicry approach to imitate nature and deal with solution-based and problem-based approaches.

- Using the biomimicry principles to enhance the building efficiency and its adaptation.
- Using biomimicry principles to achieve a productive design.
- Using biomimicry design spiral to develop any conceptual idea into a real design.
- Dealing with innovation principles to reach a successful building.
- Using biomimicry levels to simulate nature its principles, levels, behavior, and patterns.
- Analytical studies should be conducted on the principles that simulate nature and try to apply its principles correctly and simply.
- Designers should be encouraged to simulate nature because it reflects positively on nature and the building to raise the efficiency of the building, improving its performance and adapting it to changing conditions.
  
- Teaching this direction in universities and allowing students to apply it to different designs.
- Efforts should be made to establish an architectural database of biomimetic strate

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