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# Form and Biomimicry and Its Impact on Sustainable Design

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## الشكل والمحاكاة الحيوية وتأثيرهما على التصميم المستدام

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**Abstract**
The concept of nature imitation (Biomimicry) and its impact on sustainable design is beneficial for maintaining ecological balance, a vital topic given the threats facing our planet. This research explores the influence of nature-mimic architectural thought on the sustainability of the built environment. It then develops an evaluation model for nature-mimic architecture based on levels of design that impersonate nature. This model aims to measure and evaluate the mimicry of modern environmental projects in the Arab world, aligning them with the principles and concepts of nature-mimic architecture. The evaluation model is then applied to selected projects chosen as a case study. These projects were analyzed throughout their lifecycle using indicators for measuring nature-mimic architecture. The research includes a comparative analysis of the selected projects to identify those that most closely mimic nature and to utilize this as a benchmark for environmental projects in the Arab region.

**Keywords:** Shape , Nature Simulation (Biomimicry) , Sustainable Design.

**الملخص**
يُعدّ مفهوم محاكاة الطبيعة (المحاكاة الحيوية) وتأثيره على التصميم المستدام مفيدًا للحفاظ على التوازن البيئي، وهو موضوع بالغ الأهمية نظرًا للمخاطر التي تواجه كوكبنا. يستكشف هذا البحث تأثير الفكر المعماري المُحاكي للطبيعة على استدامة البيئة المبنية، ثم يطور نموذجًا تقييميًا لهذا النوع من العمارة، قائمًا على مستويات التصميم التي تُحاكي الطبيعة. يهدف هذا النموذج إلى قياس وتقييم مدى محاكاة المشاريع البيئية الحديثة في العالم العربي للطبيعة، ومواءمتها مع مبادئ ومفاهيم هذا النوع من العمارة. بعد ذلك، يُطبّق نموذج التقييم على مشاريع مختارة كدراسة حالة، حيث تم تحليل هذه المشاريع طوال دورة حياتها باستخدام مؤشرات لقياس مدى محاكاة الطبيعة. يتضمن البحث تحليلاً مقارنًا للمشاريع المختارة لتحديد تلك التي تُحاكي الطبيعة بشكلٍ أدق، واستخدامها كمعيار مرجعي للمشاريع البيئية في المنطقة العربية.

**الكلمات المفتاحية:** الشكل ، محاكاة الطبيعة (المحاكاة الحيوية) ، التصميم المستدام.

## Introduction

Over the past three decades, the environment has witnessed serious crises, such as the depletion of non-renewable resources, the depletion of ozone layer, and many other phenomena resulting from human misuse and exploitation of the surrounding environment. Despite rapid scientific advancements, successive breakthroughs, and the proliferation of contemporary local and global architectural trends that have attempted to

achieve sustainability goals, including biomimicry, architects have varied in their application of biomimicry. Their ability to understand and utilize the role that biomimicry plays in achieving sustainability principles has become evident. Various trends have emerged that focus solely on form without considering the true reasons for form's role in sustainability. Consequently, a purely formal architecture has been replicated, bearing no relation to the concept of a living, organic nature. This has recently led to calls for sustainability worldwide that take environmental conditions into account. To achieve sustainability through nature imitation, the paper will review the architect's awareness of nature simulation, its principles, the foundations of nature-simulating design and its levels, and derive a model for evaluating architectural projects that have simulated nature in their components, applied to the Arab environment.

## Research Problem

The need to achieve the principle of sustainable architecture through imitation of nature in forms and shapes has resulted in architectural styles that have conformed to a model of form imitation without achieving substance. This has led to an evaluation of this modern architectural approach by proposing a model to assess the suitability of imitating nature and its impact on architectural sustainability.

## Research Objective

To design a model for evaluating and measuring the suitability of shape through imitation of nature and its impact on architectural sustainability, specifically within the Arab context.

## Research Methodology

The research proceeds in three steps:
**Step 1:** A comprehensive analysis of human understanding of imitating nature, identifying its various principles, foundations, and levels of imitation.
**Step 2:** Deriving a proposed standard model from the outputs of Step 1 to measure the imitation of shape/form in nature and attempting to apply it to a local and an international project.
**Step 3:** Applying the standard model to corroborate its validity and arriving at the most important results and recommendations that contribute to the sustainability of architecture through the imitation of natural forms.

## Previous Studies

1.Elgohary, Farouk, Amr, (2009), "Second Nature Architecture: A New Design Trend of Environmental Design", Ain Shams Journal of Architecture and Urban Planning.
The concept of nature-inspired architecture is essential because it addresses a significant part of the needs of society and the environment as a whole. Therefore, this research discusses the concept of technology and the information revolution, and the technological impact of this revolution on architecture. It then examines the future of digital technologies and their effect on achieving the principles and objectives of nature-inspired architecture as one of the modern trends in environmental architecture.
2.Parnell, Steve, (2012), "Designing the Future", the EMBO Journal.
At the Manchester School of Architecture seminar, urbanization and industry were reflected. Steve Parnell wrote that students from the Manchester School of Architecture's MA program in architecture and urban planning were hosted by the "Consumer" seminar at the International Foundation. Anthony Burgess explained in several seminars that nature is a fundamental factor in reviving and inspiring architecture. Michael Pollon argued that the old style was also inspired by nature, but a blind imitation without promotion. The high-tech movement (21) applies natural systems to artificial problems in shaping and building. The architecture of the future is a source of the surrounding nature.
3.Ghonimi, Ibrahim, Islam, (2012), "Architecture Manifestation of Natural Scientific Paradigm". International Journal of Architecture and Design, ISSN: 2051-5820.
This research examines the relationship between scientific revolutions and their impact on contemporary architecture, exploring the methodologies that led to qualitative shifts in the scientific exploration of nature and reshaping of the natural and architectural landscape according to the formulation of architectural language. Humans have traced nature throughout history, and architects have clearly striven to understand its form.
Therefore, it is important to determine the extent to which design principles derived from the classical scientific model differ from those that complicate the scientific paradigm. Changing the scientific paradigm can increase and deepen our scientific knowledge of nature.

## 1.Human Awareness of Imitating Nature

Nature has bestowed a gift to science because it has proven its worthiness to withstand time. Nature has gone through serious and integrated crises throughout its life (8.3 billion years), which is nothing compared to the life of Man. We find that natural organisms have been

interacting with the environment for millions of years in a successful and sustainable way, without natural resources disappearing or the environment being polluted.
This is the basis of 'biomimicry'. Therefore, 3.8 is the key number in our discussion; it's the symbol of biomimicry and encompasses all the details of imitating nature. The organization Biomimicry (3.8) emerged, named after this code due to the aforementioned experience of Earth's survival and evolution since the emergence of the first life forms (Biomimic.org, 2017). Its mission is to train, equip, and connect scientists, engineers, architects, educators, and other innovators with nature in a sustainable way (AskNature.org, 2016). As Benius wrote in her book, (Biomimicry: Innovation Inspired by Nature): "With nature, there is already a sustainable world; we just need to open our eyes to see the answers to sustainability all around us." She believes that natural wisdom is shaping the future. (Biomimic.org, 2016).
Early humans were aware of nature and managed their lives according to their surroundings, interacting consciously with it despite their primitiveness and spontaneity. Now, however, despite advancements in technology and science across all fields, humanity has neglected nature and the importance of connecting with and caring for it. Instead of technology helping to harmonize with nature, it has begun to encroach upon and damage it, leading to its degradation and, consequently, the degradation of humanity itself. This has led to the emergence of biomimicry, which aims to achieve integration between humanity and its environment. (Foda, 1991, "Environment & Architecture").

| | | | | | | |
|---|---|---|---|---|---|---|
| Fear of nature | → | Interpreting nature | → | Learning from and emulating nature | → | Creating a sustainable design that reflects nature |

**Figure (1):** Illustrates the evolution of the human relationship with nature
**Source: Researcher**

## 2.Principles of Biomimicry

God gave us the wisdom and will to learn and created nature to be our teacher for survival on Earth. Nature is not only a source of the wealth extracted from it for mankind, but also a source for transforming our way of thinking. We see nature as a model, a standard, and a teacher. This vision will be a fundamental entry point, guiding us to emulate it correctly. As a result of the interaction between humanity and nature, we find that nature is a source of inspiration for humanity in general and for architects in particular. Architects describe buildings as reflecting the conditions of society, as units belonging to nature, forming possibilities that emulate nature. These possibilities interact in a renewed and continuous manner, making humanity feel as if it is part of nature, not an intruder. By identifying natural forces, the first orientation of human construction was determined, translating the relationship with nature into a strategy of symbolic systems, formal relationships, and material manifestations produced by intellectual manifestations resulting from the aspiration towards nature.
After a simple reference to the concept of nature and the relationships between (man, nature, and architecture), the researcher will find that the theoretical dimension of the nature-imitation architecture trend is (the interactive relationship of man with nature and the transmission of meanings according to the intellectual positions resulting from looking towards the surrounding environment, including formal systems and material manifestations).

### 2-1 Nature as a Model

Humans rely on nature's behavior in shaping modern design. Nature plays an important role in human awareness to find new ways to develop life in the future, so that there is no waste within nature, but rather there are interconnected systems within the ecosystem. Waste from organisms can be used as byproducts for the needs of other organisms. This confirms the idea of solving the problems of living organisms sustainably. For example, by using animal waste and some simple compounds with the sun, we produce biodegradable materials used in interior design

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such as (fibers, ceramics, and plastics). Figure (2) shows steel fibers woven like spider web patterns, and colors derived from butterfly wings.

Benyus, (2017), "Biomimicry: Innovation inspired by nature"

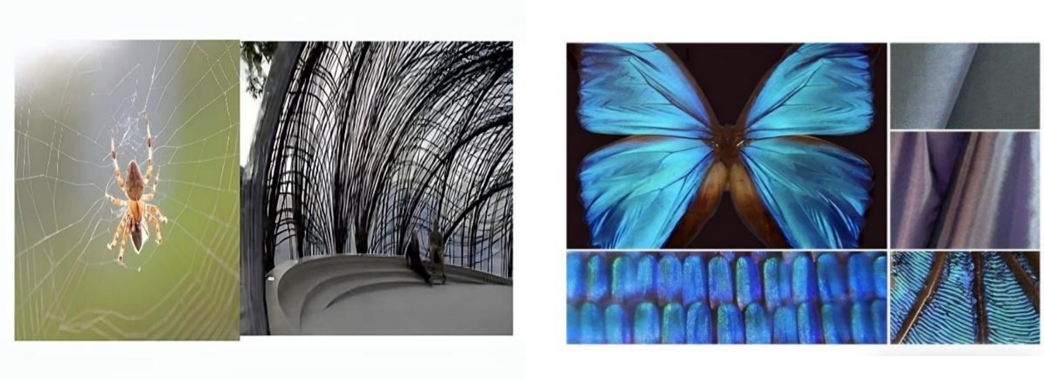


**Figure (2):** Shows the architect’s simulation of woven fibers as a spider’s thread pattern and the derivation of the colors found on butterfly wings.

**Source**: **https://biomimicrey.org**

## 2-2 Nature as a standard

Man considers the environment to be the basic standard for judging the validity of our innovations according to the organization of imitating nature, given the biological adaptation applied within nature by the Creator to provide optimal functions for nature, which is a miracle of God in His ability to sustain nature, and the interaction of its beings, which indicates mercy and strength.

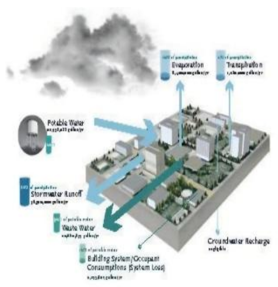
Figure (3) clearly shows the use of the ecological balance method in life in the plan of the Lloyd Portland Oregon area in the United States.

(2016) http://scienceandquran.com

**Pre-development Water Use Conditions**

**2004 Existing Water Use Conditions**

**Pre-Code Water Use Conditions**



**2050 Pre-Plan Water Use Conditions**

**Figure (3)** illustrates the use of the ecological balance method in life in the Portland, Oregon State Plan in the United States of America.

**Source**: **http://science andquran.com (2016)**

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### 2-3 Nature as a Teacher

There is a strong relationship between the ecosystem and the human environment, as human thinking changes with the view of nature as a source of raw materials, and as a teacher of its ability to solve problems, as it has wisdom and knowledge in order to survive in a sustainable way. Imitating nature is a way to evaluate nature and a way to motivate designers to look at nature more deeply to reach new perceptions that exist but are not clearly visible on the surface. Baumeister, D. "Bio-mimicry Presentation at the University of Seattle, USA, Washington College of Architecture" (2007)

Figures (4), (5), and (6) illustrate different examples of nature simulation.

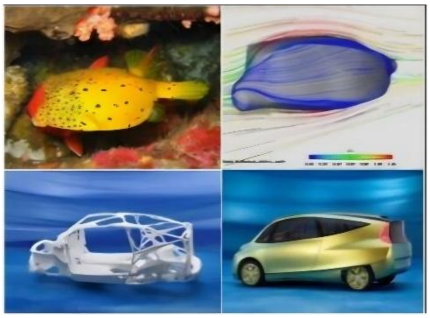
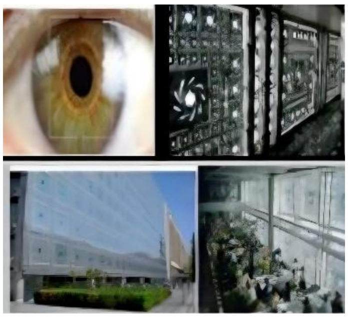




**Figure (6)** **Figure (5)** **Figure (4)**

Figure (4): Simulation of a lotus flower using self-cleaning paint.
Figure (5): Simulation of the cornea of an Arab world building. Figure (6): Simulation of a fish skeleton and its use in a car body.

**<u>Source</u>: Baumeister, D., (2007), "Bio-mimicry Presentation at the University of Washington College of Seattle, USA. Architecture"**

### 3.Foundations of Biomimicry Design

The Biomimicry Institute has provided two tools to assist the process of biomimicry, namely the "design lens" as shown in Figure (7), and the different directions of the design lens according to biological nature as shown in Table (1). It is a seven-step guide that helps the designer to look deeply at solving a biological problem instead of repeating the superficiality of nature in the design. It is a sequential and clear process in order to produce a design inspired by nature that uses solutions found in nature to solve problems in creative ways. (Biomimicry.net, 2017)

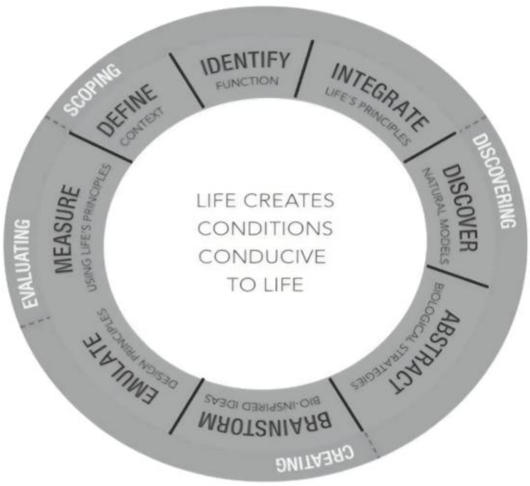



**Figure (7)** illustrates the design lens used in biomimicry.

**<u>Source</u>: biomimicry.net**

- Step 1 (**Identify**) Functional Defining: This involves identifying the core problem and outlining the design specifications to solve it. This is done by defining the primary function of the design.
- Step 2 (**Integrate**) Biological nature: Studying nature biologically, is nature capable of performing the function that has been identified to solve a problem? The most important feature of the problem-solving tool is that it requires looking at different results from 3.8 billion years of environmental research and development that has occurred in nature to produce complex sustainable systems, by identifying specific conditions under which a function is achieved in nature such as climate, food, social and temporal conditions, research and study has become more specialized than probabilities.

(Zari, Maibritt Pedersen (2009): Biomimetic approaches to Architectural design for increased Sustainability.

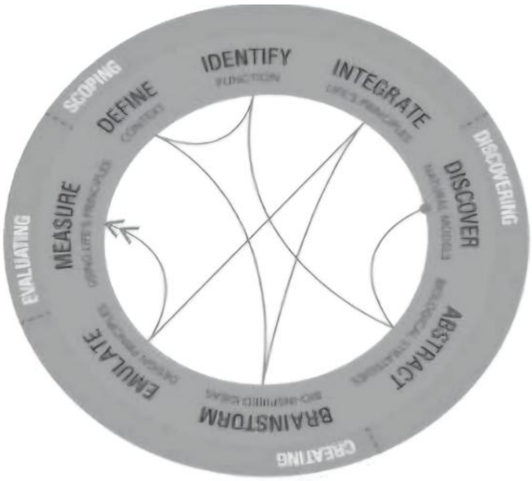
- Step 3 (**Discover**) Discovering biological nature: Discovering specific examples and models of biological solutions to the problem. Living organisms strive to challenge the changes in nature in order to survive. It is recommended to cooperate with a biologist at this stage to advance biological knowledge.
- Step 4 (**Abstract**): Search for recurring patterns and processes in nature that achieve success in sustainability and survival. These can clarify the essence of the processes without neglecting hidden phenomena, and then send the details and concepts reached to multiple disciplines.
- Step 5 (**Emulate**): Develop viable solutions based on lessons learned from nature (form, function, and ecosystem). This step involves developing practical solutions to design challenge based on the natural models identified in the previous steps. The site is a key metric for the solution and must be carefully considered, as it represents the link between the design and the surrounding environment to ensure sustainable environmental outcomes.

Reap, J., Baumeister, D. & 8135, B. (2005) “Biomimicry and Sustainable Engineering”, ASME International Mechanical Engineering conference and
Exposition. Orlando, FL, USA.

- Step 6: (**Evaluate**) Evaluate solutions according to the principles of life. This step includes how to evaluate the design according to or against the "principles of life" by asking questions such as, "Does the design evolve according to nature? Does it adapt to changes that occur? Is the design a closed loop (self-sufficient)?" Through these points, we reach sustainable results.
- Step 7: (**Define**) This additional step restarts the process with a deeper understanding of the problem and considers the issues identified in the previous steps as "assessment". This aspect of the tool is what makes the iterative process lead to more specific and accurate results, mimicking nature and the learning and adaptation process that occurs through repeated feedback loops.

**Table (1)** illustrates the design lens trends according to biological nature

**Source: Seattle, « Baumeister, D., (2007), "Bio-mimicry Presentation at the University of Washington College of Architecture", USA.**

<table>
<tr><th>Type 1: Biology to Design</th><th>Type 2: Challenge to Biology</th></tr>
<tr><td>


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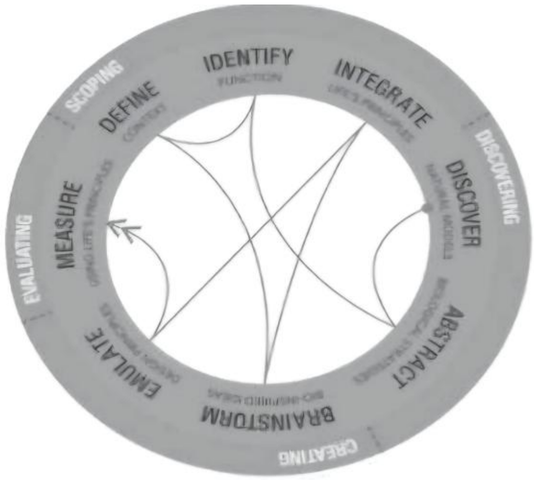

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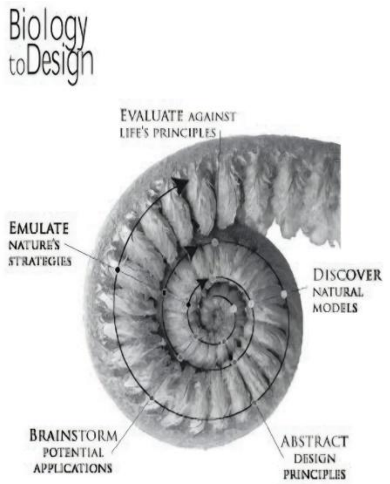

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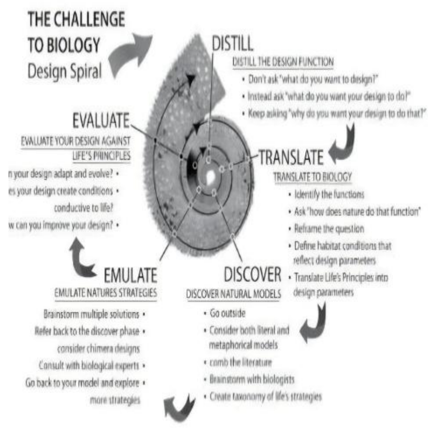

Figure 3: Design Spiral Methodology (used with Permission).
</td></tr>
<tr><td>Discovering Nature's Patterns (Summary of Design Principles - Simulating Natural Strategies - Evaluating Principles against Life Principles - Challenging Biological Nature)</td><td>Defining Function - Defining Context - Challenging Biological Nature</td></tr>
</table>

## 4- Levels of Biomimicry Design

By classifying nature into three levels, humans can define its vitality and how to emulate it. These levels are: (living organisms, natural behavior, and the ecosystem). Within each of these levels, there are five dimensions of biomimicry. Biomimicry can be achieved in terms of (shape, building materials, construction methods, the same processes that occur in nature, and the design's ability to perform this same function).

### 4.1 Level of Biomimicry:

This involves imitating a specific organism, such as a plant or animal, in terms of (shape, building materials, construction methods, the same processes that occur in nature, or the design's ability to perform the same function) - that is, any one of these elements. Figure (8) shows the Ministry of Municipal Affairs (MMAA) building in Qatar, which is a biomimicry

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of a cactus, not in form, but in its function and its successful survival in hot, dry environments and its adaptation to the desert climate. The tower was made sustainable in an energy-efficient and nature-based way, and implemented the use of sunshades that can be opened and closed automatically according to the intensity of sunlight during the day to protect from the heat. This is similar to how the cactus is selected to perform transpiration at night.


**Fig. (8):** Cactus Building, (MMAA) in Qatar 2015

**<u>Source</u>: Cactus Building, (MMAA) in Qatar 2015**

### 4.2 Level of Nature's Behavior

Imitation of the behavior of living organisms depends on functions and relationships in terms of (shape - building materials - construction method - function). Figure (9) shows the East Gate Centre in Harare, Zimbabwe, which is inspired by termite mounds. Architect Michael Pearce based his design on the structure of termite mounds. The East Gate building is fully ventilated, cooled, and heated using natural means. The building consists of four external stone walls and an internal atrium seven stories high. Outside air is drawn in through numerous ventilation openings and then either cooled
or heated by the building's mass, depending on which is hotter: the building's concrete or the air. Moreover, this system costs one-tenth (1/10) of the cost of conventional building air conditioning and consumes 35% less energy than six conventional buildings.

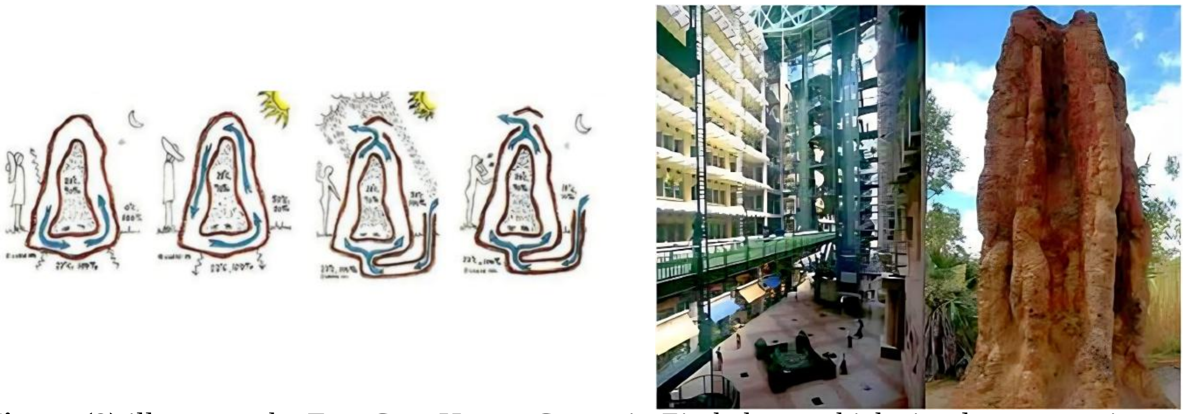

**Figure (9)** illustrates the East Gate Harare Centre in Zimbabwe, which simulates a termite mound.
**<u>Source</u>: [http://www.ibda3world.com/10-green-structural-engineering-marvels](http://www.ibda3world.com/10-green-structural-engineering-marvels)**

### 3.4 The Ecosystem Mimicry Level

This is an integral part of biomimetic design, as described by Vincent J. F. V. O. Bogatyrev, O. A., Bogatyrev, N. R., Bowyer, A. & Pahl, A.-K., April (2006), "Biomimetic - its practice and theory." It involves deconstructing the design problem and developing solutions based on

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the changes in nature, including past functions, processes, and solutions. This is followed by emulating the principles of nature's genius that are relevant to the design problem, enabling the design to be employed sustainably and successfully as part of a complex system. This allows for leveraging the relationships between different processes in nature, ultimately leading to the foundations of the entire ecosystem. The ecosystem level of biomimetic design aims to integrate with nature based on six principles of nature-based design. Figure (10) methods of utilizing nature:

1- Construction using recycled materials, sand, and clay (local materials).
2- Heating and cooling: from the sun and the earth.
3- Water Harvesting: Roofs capture rainwater and dew, mimicking the Namibian body of a beetle.
4- Renewable Electricity: Solar and wind energy are stored to generate electricity.
5- Wastewater Treatment: Greywater from showers and dishwashing is treated and separated from black water from bathrooms, then reused for irrigating plants and flushing toilets.
6- Food Production: Food is produced from plants irrigated with the treated greywater.

The figures of (Tomorrow Tower) illustrate the biomolecular strategies implemented throughout the building. Wastewater is reused for garden irrigation. Curves are designed across the entire building's footprint, maximizing air circulation to avoid excessive construction costs. The entire south façade is composed of solar panels, providing solar and electrical power to the building.
http://www.biometric-architecture.com(architecture.com2010)


**Fig. (10):** William McDonough's Tree Scraper of Tomorrow
**Source: https://biometric-architecture com/2010william-mcdonoughs-treescraper**

**From the previous theoretical study** of human perception of nature mimicry, identifying its most important principles and its connection to sustainability, the researcher was able to determine the most important governing principles of biomimic design. The researcher was able to deduce the most important design levels and standards that mimic nature and have a positive impact on architectural sustainability.

Therefore, a model will be designed to evaluate and measure the extent of biomimicry and its impact on architectural sustainability. This model will be applied to two architectural projects with the same governing philosophy, specifically within the Arab context:

### 4. Calculating the Relative Average of the Evaluation Result:

1- A fundamental constant for the building's interaction with the surrounding environment, representing the largest percentage in the evaluation model (60%).
2- A constant selected from three variables representing the basic levels of biomimic design, representing 40%, as shown in Table (2).

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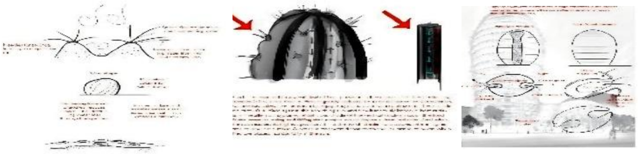
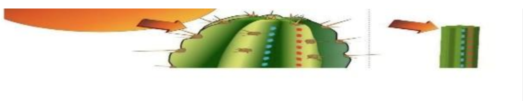
| Table (2) illustrates the proposed standard model for simulating form in nature | | | Evaluation Percentage | |
|---|---|---|---|---|
| Imitating Living Organisms | Shape / Form | The form resembles the form of a living organism | 8% | 40% |
| | Building Materials Used | The building is constructed in the same way as the living organism to represent the imitated model | 8% | |
| | Structural System | The building functions in the same way as the living organism to represent the imitated model | 8% | |
| | Process | The building functions in the same way as the living organism divides to represent the imitated model | 8% | |
| | Function | The building's function resembles the living organism in the depth of its structure | 8% | |
| Imitating Nature Behaviour | Shape / Form | The building resembles the way the living organism builds its home | 8% | 40% |
| | Building Materials Used | The building is constructed from the same material as the living organism, thus representing the living organism | 8% | |
| | Structural System | The building is constructed using the same methods as the living organism in terms of its construction (suitability to the place and time) | 8% | |
| | Process | The building functions in the same way as the living organism in combining (precise orientation, form, building materials, and ventilation) | 8% | |
| | Function | The building's function is similar in the same way to the function performed by the imitated organism | 8% | |
| | Shape / Form | The building resembles an ecosystem (it resembles the life of the imitated organism) | 8% | 40% |
| | Building Materials Used | The building is constructed from the same type of materials used in the environment of the metaphorical organism, employing them as natural compounds shared with water and utilizing them as a chemical building agent | 8% | |
| | Structural System | The building is assembled in the same way as the metaphorical organism's ecosystem (using creation principles with increasing complexity over time) | 8% | |
| | Process | The building functions in the same way as the organism within the ecosystem (e.g., harnessing and converting energy from the sun, storing water) | 8% | |
| | Function | The building is capable of functioning in the same way as the metaphorical organism within the ecosystem, thus forming part of a complex ecosystem | 8% | |
| Interacting with the surrounding environment | | Adapting to changing conditions | 20% | 60% |
| | | Energy conservation | 20% | |
| | | Utilizing modern technological methods that promote architectural sustainability | 20% | |

## Second: Selecting Study Samples:

## The samples are selected based on several criteria:

1- Their apparent formal features are linked to the imitation of nature.
2- The buildings adhere to the principles of environmental architecture.
3- Digital technology is used in environmental treatments and natural forms.
4- These buildings fall within a specific time period of the past ten years.
5- The project samples are at the regional level (the Arab environment)

**Table (3) shows analysis of the study samples. Source: (Researcher)**

| | | | |
|---|---|---|---|
| Ministry of Municipality and Urban Planning Building Project in Doha, Qatar (Cactus) | | | |
| Project Overview | The building is designed to meet all its energy needs through clean energy sources such as solar power, and it also features an internal plant dome. It is worth noting that this project will be part of a larger initiative, Energy City, which will be the world's first city built solely for energy and will be located northeast of Doha. The windows can be opened or closed to adjust to the prevailing temperature, mimicking the transpiration activity of a cactus at night instead of during the day to conserve water. | | |
|  | | | |
| Designer | Architectural Bureau in Babcock | Date of Construction | 2009 |
| Classification: | Administrative Building | Cost | 2.6 Billion dollars |
| Location: | Doha, Qatar | | |
| **Interacting with the surrounding environment** | Use of the latest technological methods that adopts building sustainability | - Choosing energy-efficient building systems.<br>- Relying on solar energy to generate electricity using solar cells and converting them into electrical power. | |
| | Adapting to changing conditions | The building achieved self-regulation through sunshades on the windows, which can be opened or closed to match the prevailing temperature, and by mimicking the activity of a cactus that transpires at night rather than during the day in order to conserve water dynamically. | |
| | Energy Conservation: | By installing sunshades on windows, you can open or close them to match the prevailing temperature, and mimic the activity of the cactus, which transpires at night instead of during the day in order to conserve water.<br> | |
| | Design Study (Form) Levels of nature and living organism imitation are studied. | -Structural System: The form of the building mimics that of a cactus.<br>Process: The design mimics the transpiration process of a cactus, utilizing sunlight through windows that can be opened or closed to adjust to the prevailing temperature. | |
|  | | | |
| Project Two: **BUSINESS – BARK** | | | |
| Project Definition | The design concept for this project was based on extending the project's impact from the architectural framework of an independent administrative building to the urban framework of the city center, and how to achieve a connection between the main street and the back street through the building. Therefore, the design concept relied on the atrium space extending within the building to achieve functional and environmental goals, namely a pedestrian axis connecting the main street and the back street. It was utilized as a covered pedestrian walkway within the building's mass, thus maximizing movement and consequently increasing the attractiveness of the commercial spaces on the ground floor. | | |

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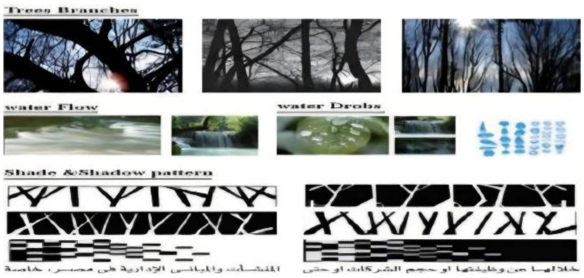
<table>
<tr><td colspan="4">  </td></tr>
<tr><td>Designer</td><td>Al Jaili Architects</td><td>Date of Construction</td><td>Underway</td></tr>
<tr><td>Classification:</td><td>Entertainment Administrative Building</td><td>Cost</td><td>50 Million Dollars</td></tr>
<tr><td>Location:</td><td colspan="3">Fifth Settlement, new Cairo</td></tr>
<tr><td rowspan="3">Design (Form) Study</td><td>Structural System Study</td><td colspan="2">Reliance on Concrete in the Building Structural Framework<br></td></tr>
<tr><td>Levels of Levels of Nature Imitation Study are studied</td><td colspan="2">The building mimics the form of nature through the trees on the facade<br></td></tr>
<tr><td>Imitating Nature's Behavior</td><td colspan="2"></td></tr>
</table>

**Table (4) shows the analysis of the study samples. Source: (Researcher)**

<table>
<tr><th></th><th colspan="3">Measurement criteria derived from the theoretical section</th><th>Project One</th><th>Project Two</th><th>Effect of the axis on straightness</th></tr>
<tr><td rowspan="10">Theme 1: Levels of Nature Imitation</td><td rowspan="5">Imitating Living Organisms</td><td>Shape / Form</td><td>The form resembles the form of a living organism</td><td>*</td><td>*</td><td rowspan="10">25%</td></tr>
<tr><td>Building Materials Used</td><td>The building is constructed in the same way as the living organism to represent the imitated model</td><td>--</td><td>--</td></tr>
<tr><td>Structural System</td><td>The building functions in the same way as the living organism to represent the imitated model</td><td>*</td><td>--</td></tr>
<tr><td>Process</td><td>The building functions in the same way as the living organism divides to represent the imitated model</td><td>*</td><td>--</td></tr>
<tr><td>Function</td><td>The building's function resembles the living organism in the depth of its structure</td><td>--</td><td>--</td></tr>
<tr><td rowspan="5">Imitating Nature Behaviour</td><td>Shape / Form</td><td>The building resembles the way the living organism builds its home</td><td>--</td><td>--</td></tr>
<tr><td>Building Materials Used</td><td>The building is constructed from the same material as the living organism, thus representing the living organism</td><td>--</td><td>--</td></tr>
<tr><td>Structural System</td><td>The building is constructed using the same methods as the living organism in terms of its construction (suitability to the place and time)</td><td>--</td><td>--</td></tr>
<tr><td>Process</td><td>The building functions in the same way as the living organism in combining (precise orientation, form, building materials, and ventilation)</td><td>--</td><td>--</td></tr>
<tr><td>Function</td><td>The building's function is similar in the same way to the function performed by the imitated organism</td><td>--</td><td>--</td></tr>
<tr><td rowspan="5"></td><td rowspan="5">Imitating the Ecosystem</td><td>Shape / Form</td><td>The building resembles an ecosystem (it resembles the life of the imitated organism)</td><td>--</td><td>--</td><td rowspan="5"></td></tr>
<tr><td>Building Materials Used</td><td>The building is constructed from the same type of materials used in the environment of the imitated organism, employing them as natural compounds shared with water and utilizing them as a chemical building agent</td><td>--</td><td>--</td></tr>
<tr><td>Structural System</td><td>The building is assembled in the same way as the imitated organism's ecosystem (using creation principles with increasing complexity over time)</td><td>--</td><td>--</td></tr>
<tr><td>Process</td><td>The building functions in the same way as the imitated organism within the ecosystem (e.g., harnessing and converting energy from the sun, storing water)</td><td>--</td><td>--</td></tr>
<tr><td>Function</td><td>The building is capable of functioning in the same way as the imitated organism within the</td><td>--</td><td>--</td></tr>
</table>

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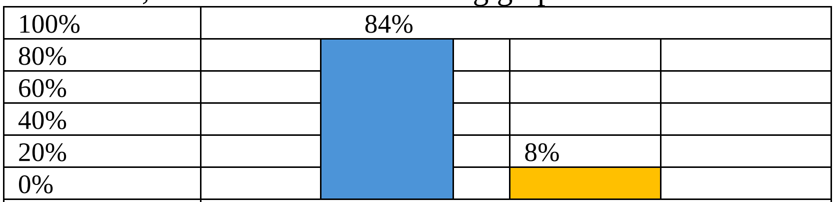
| | | | | | | |
|---|---|---|---|---|---|---|
| | | | ecosystem, thus forming part of a complex ecosystem | | | |
| Interacting with | Adapting to changing conditions | | | * | -- | 50% |
| | Energy conservation | | | * | -- | |
| | Utilizing modern technological methods that promote architectural sustainability | | | * | -- | |
| | The percentage of the indicator present for each project individually, in terms of the two study themes. | | | 84% | 8% | |

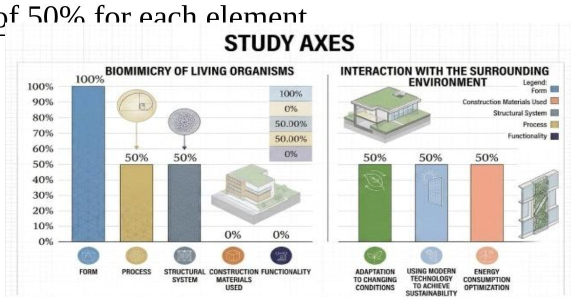
- As a result of the comparative analysis between the two projects (Cactus Building), (BARK BUSSINES), the Cactus Building project achieved the principles of nature simulation at a rate of 84%, while the second project (BARK BUSSINES) achieved the principles of nature simulation at a rate of 8%, as shown in the following graph:




| | |
|---|---|
| First Project | 84% |
| second project | 8% |

**Figure (11):** Percentages of the comparative analysis results for the study samples.
**Source: Researcher**

- The principles of simulation (mimicry) were based on two main themes in the table: The first is the levels of imitating nature, which was achieved at a rate of 24%. Imitation of the form was achieved at a rate of 100% at the level of the two projects, while the simulation of the structural system and the design process were achieved at a rate of 50% at the level of two projects for each of these themes. The second is interaction with the surrounding environment, which was achieved at a rate of 60%. This theme was achieved in the first project and was not achieved in the second project through some elements such as adapting to conditions, rationalizing energy consumption, and using modern technological methods that work on the building sustainability, which were achieved at a rate of 50% for each element




| | Biomimicry | Adapting to Surrounding Conditions |
|---|---|---|
| Form | 100% | |
| Building Materials Used | 0% | |
| Structural System | 50.00% | |
| Process | 50.00% | |
| Function | 0% | |
| Adapting to Changing Conditions | | 50% |
| Using Modern Technology to Achieve Sustainability | | 50% |
| Energy Rationalization | | 50% |

Figure (12) shows the percentages of the comparative analysis results for the study samples.
**Source: Researcher**

Pursuant to the foregoing, we conclude that the second project imitated the form without considering the vital function of the building and how it interacts with the surrounding environment. If it had achieved the element of rationalizing energy consumption through external coverings and the use of modern technological methods to adapt to changing conditions, it would have been possible to imitate nature, as they say, and not just imitate it.

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