Biomimicry as an innovation in modern Architecture Design

Dr/ Sarah Fathy Ahmed Fahmy
Lecturer - interior design and furniture department,
Faculty of Applied Arts,Damietta University, Egypt

Abstract

Biomimicry is a design concept mimicking the nature, as an established sustainable system, as a mentor and a great source of inspiration through observing its models, systems, and processes, could help in reaching sustainable development, not only in environmental stewardship, but also in economical and social aspects as well. As a method for sustainability biomimicry constitutes the ability to help achieve sustainable development.

Biomimicry can be defined as imitating or getting inspiration from the nature's structures and processes to find solution for human's problems. It is a new concept in architecture. Biomimicry can be considered as a multi- level method and a methodology of design which had underlying basics about learning from the nature and getting inspiration from it.

Problem of this research is that the implications of Biomimicry method in architecture design had not been fully explored. This paper aims to incorporate this method into the idea of generation phase of the architecture design and development process within the context of design. The purpose of this paper is to introduce and create interest by the designers in the ideology of biomimicry that refers to sustainability by looking to the nature for answers because such a method brings into view a method for design taking into consideration the possibility of creating buildings inspired by the nature.

Key words: Biomimicry, Bio-inspired design, Biomimetic Architecture

•ملخص البحث (باللغة العربية)

تعد المحاكاة العضوية (البيوميمكرى) أحد الأنماط الحديثة التى تعتمد على النظام البيئى كأساس للمحاكاه والتصميم من خلال هذا المفهوم (concept) وهو الفكرة العامة له والغرض منه تحقيق فهم عام لموضوع ما ويكون هذا المفهوم فى مجال العمارة من خلال تحديد مسار للفكرة مستمد من عنصر أو شكل معين.

ويتناول البحث بالدراسة والتحليل لها كأحد الأساليب والأنماط الحديثة فى مجال العمارة، وذلك من خلال محاكاة الطبيعة وإتخاذها كمصدر للإلهام وتقديم حلول مبتكرة لحل المشكلات التي تواجه الانسان. يعتبر إتجاه المحاكاة العضوية منهجية متعددة المستويات في التصميم والتي لها مبادئ ومفاهيم تستلهم من الطبيعة.

تكمن مشكلة البحث فى أن تطبيق أساليب المحاكاة العضوية لم يتم استغلالها والإستفادة منها من قبل المصممين بشكل وافي حتى الآن. و تهدف هذه الدراسة إلى دمج هذا المفهوم في التصميم المعماري وتداخلها في سياق التصميم ، كما تهدف الدراسة الى الإستفاده من الأساليب و الأنماط الحديثة فى مجال العمارة لإثراء الفكر التصميمى لدى المصممين بإستخدام مفهوم المحاكاة العضوية التي تحقق الإستدامة البيئية للبحث عن حلول غير تقليدية، وتصميم مباني حديثة تتوافق مع البيئة. تقوم الدارسة داخل البحث وفق المنهج الوصفي التحليلي من خلال وصف وتحليل لبعض الأمثلة والأنماط الحديثة فى مجال المحاكاة العضوية (البيوميمكرى).كما أنه من المتوقع أن إلقاء الضوء على الأساليب الابداعية الحديثة فى مجال العمارة سينعكس بشكل إيجابى على المصمم الداخلى وفكره الإبداعى بشكل خاص وعلى المجتمع بشكل عام.

Introduction:

Architectures and designers had always been inspired by the nature. Throughout history, structures, systems, and materials developed by designers had had roots in natural structures, systems, and materials. For example, the echolocation used by bats to navigate in the dark had led to innovations in cane technology for blind people. Others had looked to the methods of drawing water from fog beetles use, or how a lotus leaf can help keep moisture away from the surface this had led to changing the surface of fabrics at the nano-scale so they repel water. And gecko tape imitates the feed of a gecko lizard by including nanoscopic hairs. Other designers had looked to the way tower building termites had structures designed to maintain a stable temperature in climates with wide temperature swings. [33]

Biomimicry as a design concept taking the nature, an established sustainable system, as a mentor and a great source of inspiration through observing its models, systems, and processes, could help in the pursuit of sustainable development, not only in environmental stewardship, but also in economical and social aspects as well. As an method for sustainability, biomimicry constitutes the ability to help achieve sustainable development.

Problem of Research:

The implications of biomimicry method in architecture design had not been fully explored.

Aim of Research:

The purpose of this paper is to introduce and create interest by the designers in the ideology of biomimicry that refers to sustainability by looking to the nature for answers.

What is Biomimicry

Bios means life and Mimesis means to imitate. Biomimicry is defined as imitating or taking inspiration from the nature’s forms and processes to find solution forhuman’sproblems

.As the design community realizes the tremendous impacthuman'sconstructions had on the world, environmental designers look to methodes like biomimicry to advance sustainable design. [9]

Biomimicry,as a term emerged approximately fourteen years ago,it proved to have the ability as an method leading towards sustainability. Looking at the nature, beyond being merely a resource source, as a model, measure and mentor for the production of people's needs, was an idea towards sustainable development, and a reasonable one as the nature had been a sustainable system for over 3.8 billions of years.

Biomimicry had the ability to be influential towards environmental stewardship, as an idea-generation method, as well as sustainability as a whole. [20]

Origins of Biomimicry

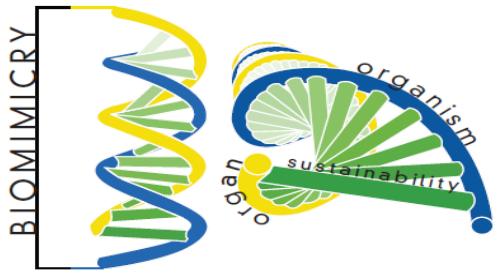


Figure (1)

The Biomimicry Helix Model by Emily Royall [3]

Biomimicry is an alternative solution in the search of sustainable building design and technology. The inspiration from the nature is driving force in architecture, resulting in majestic works of architecture. Biomimicry is about solution refined and developed by the nature. For any sustainable building design, one needs to consider structural efficiency, water efficiency, minimal or zero-waste systems, thermal environment, and energy supply. Biomimicry is about answers. Biological organisms refined and developed by natural selection over a billion year research and development period can be seen as embodying technologies, functions, and systems that are answers to the problem of surviving in the nature.

These problems are often equivalent to those encountered by human's as we seek new ways to design and live sustainably, and in many cases had find solution for the same problems with a far greater economy of means. Exploring the application of Biomimicry in current architectural design, resulting in a set of design methods, levels and basics.

Studying a leaf to invent a better solar cell is an example, it as "innovation inspired by the nature."

The core idea is that the nature, imaginative by necessity, had already find solution ford many of the problems grappling with. Living things such as animals, plants, and microbes are the ultimate designers. They had found what works, what is appropriate, and most important, what lasts here on Earth. [17]

After 3.8 billion years of research and development, failures are fossils, and what surrounds us is the secret to survival. Biomimicry is commencing as a new science that studies the nature's models and then emulates these forms, process, systems, and strategies to find solution for human's problem and sustainability. Biomimicry uses an eco-friendly standard to judge the sustainability of our innovations. After many years of evolution, the nature had learned what works and what lasts.

Biomimicry is a new way of viewing and valuing the nature. It introduces an era based not on what we can extract from the natural world, but what we can learn from it. [17]

Biomimetic thinking

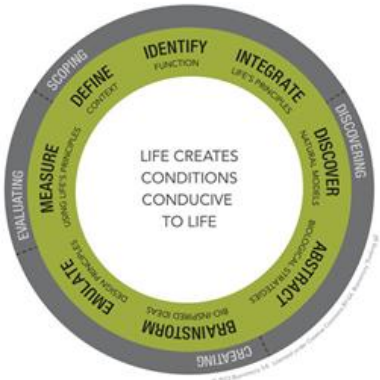


Figure (2): Biomimetic thinking [24]

The biomimicry method seeks the nature's advice at all stages of design, from scoping to creation to evaluation.

Working with "biologists at the design table," innovators explore the true functions they want their design to accomplish, and then ask: what organisms or ecosystems depend for their survival on performing those functions through survey of the biological literature reveals dozens of inspiring models, complete with physical blueprints, chemical formulae, process descriptions, and community strategies. To infuse life's systemic wisdom into the concept or design of everything from carpets to cities, a list of Life's Basics serves as an overarching scoping and evaluation tool the nature's own eco-design checklist.

But products and processes are not the only human's designs influenced by biomimicry. As more people see the nature as a teacher rather than a warehouse. [7]

Biomimetic processes

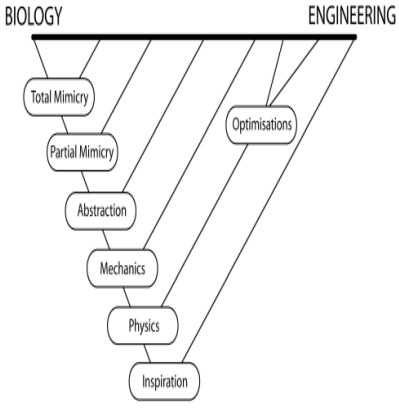


Figure (3): Map of biomimetic processes [13]

Levels of inspiration

At least there are three types of inspiration can be renowned in architecture and design, and each type plays different role. All these three provide a spectrum whose understanding is critical for the progress in design. These three levels of inspiration are named as visual, conceptual and computational.

1-Visual inspiration is quite well understood and widely used. Such a case, images of different living organisms, or their system, are used to create similarly looking engineering systems.
Example: turtle shell in the nature. [1]

2- Conceptual inspiration occurs when an structural engineer uses a principle found in the nature in design, for example, the biological principle of homeostasis. This principle states that any living organism reacts correspondingly to recover its vital functions when attacked by an external agent. A designer can apply this principle, for example, to determine the optimal design of shell roofs subjected to thermal and mechanical loads. Unfortunately, using conceptual inspiration requires a concrete understanding of nature and structural engineering and cannot be used in a mechanistic way by an automatic designing system. [1]

3-Computational Inspiration:
The computational design process allows the exploration and development of surface geometries in 3 dimensional spaces that had virtual environmental conditions. The exploration is enabled by an evolutionary module that produces populations of surfaces in many generations, and the development is governed by an algorithm that imitates organic growth. Computational design lends itself to such an method as it is enables employing complex behaving rather than just modeling a particular shape or form. [18]

Levels of Biomimicry

The first level of biomimicry is the mimicking of natural form. For instance, you may mimic the structure of an owl's feather to create a fabric that opens anywhere along its surface. Or you can imitate the frayed edges that make the owl a silent flier. Copying feather design is just the beginning, because it may or may not yield something sustainable. Deeper biomimicry adds *the second level* which is the mimicking of natural process, or how a thing is made. At *the third level* is the mimicking of natural ecosystems.[7]
There are three levels of biomimicry are:

a. Structure or form Level.

b. Process Level.

c. Ecosystem Level.[2]

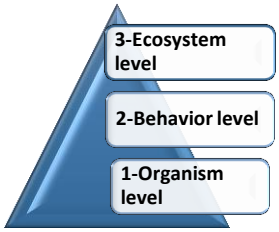


Figure (4) :Levels of biomimicry

(By researcher)

1- The first level is *Organism level* the mimicking of natural form.

2- The second level is *Behaving level* the mimicking of behaviour, and how an organism behads.

3- The third level is *Ecosystem level* the mimicking of natural ecosystems**.** [2]

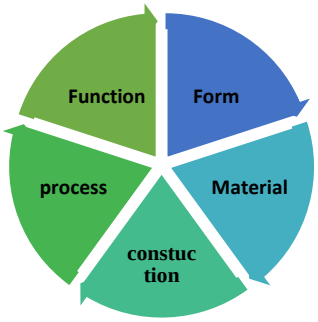


Figure (5):Dimensions of biomimicry (by researcher)

Biomimicry as a design methodology

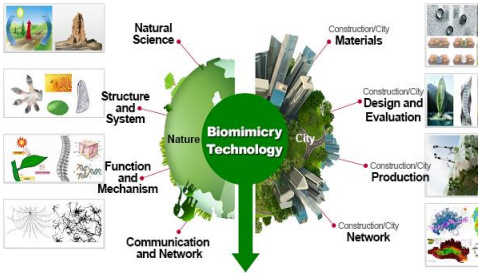


Figure (6): Biomimicry as a design methodology and technology [21]

Designers had used biology as an inspiration for thousands of years, viewing the natural world as ‘a living encyclopaedia of ingenuity’. [14]
Biologically inspired design processes typically begin from one of two starting points:
Solution-to-Problem: where a known biological solution is applied to suitable problems, or *Problem-to-Solution*: where a particular problem is tackled by searching for biological answers to analogous natural challenges. [14]

Basics underlying biomimicry:

Figure (7): Biomimicry Institute’s Design Spiral methodology [8]

By surveying the design basics enumerated by biomimicry theorists there may be many such basics , the first the principle asserts that all living beings and living systems are animated by

a will or impulse to maintain and increase their own existence. In contemporary systems theory this will-to-self-actualization as it had a longer philosophical lineage and is not confined to the terms of reference of any particular branch of science, such as systems theory.[5]

Biomimetic Architectural Method

Since concept of biomimicry methodes to architectural engineering and design is relatively new, there are a large number methodes to the matter each with its own benefits and drawbacks. Specific basics of ecosystem biomimicry for architecture had been deduced through a comparative cross-disciplinary review. It can be concluded that the incorporation of specific basics of biomimicry in architectural design we must reach high level of sustainability. Most of the articles emphadized that understanding of biology and ecology into architectural design will be significant in the creation of a built environment that contributes to the health of human's societies. [4]

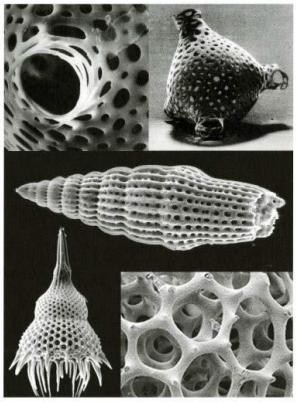


Figure (8): Design for the European Central Bank based on Radiolaria morphology [13]

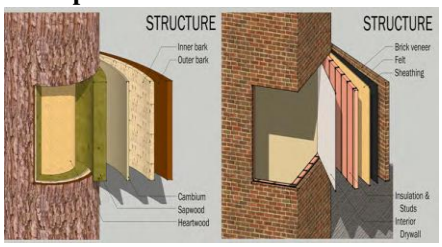


Figure (9): Comparison between natural system (left) and architectural system (right) [8]

Learning From The nature

Figure (10): Lotus leaf as an inspiration [10]

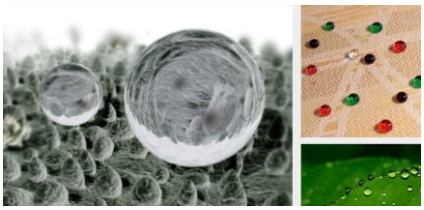


Figure (11): Example of self cleaning surfaces inspired by the lotus flowers. [16]

The science of biomimicry provides designers with a framework. Consider what the early biomimicry had accomplished it encourages behaving in harmony with the earth's processes.

In the circle of life there are some other bioimitates: [19]

• The nature uses only the energy it needs
• The nature fits form to function
• The nature recycles everything
• The nature rewards cooperation
• The nature banks on diversity
• The nature demands local expertise
•The nature curbs excesses from within.
• The nature taps the power of limits.

Life as an Inspiration in Architecture

Those kinds of the nature inspired projects are allowing architects and designers to develop eco performance basics that can be used by industry professionals worldwide to build Biomimcry answers into their own designs. In fact, into this new era of sustainability, buildings, outdoor art and other man-made structures might behave like trees and leaves, capturing, cleaning and storing rainwater; transforming sunlight to energy and carbon dioxide to oxygen; preventing soil erosion; disseminating seedlings; and eliminating waste. There is need for future young engineers and designers to initiate bio-inspired design adaptations that imitate the nature's best ideas, so that all futuristic buildings will be sustainable. [17]

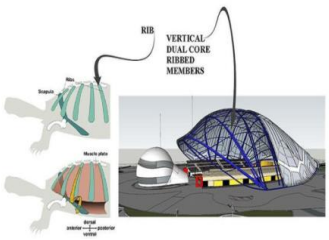
Figure (12): Architecture inspired by the nature[34]

Figure (13): Crystal palace inspired by water lily. Column structure of Roman Gatti factory after human's body's thighbone [2]

Biomimicry the nature inspired design method

Biomimicry is learning from and then emulating natural forms, processes, and ecosystems to create more sustainable designs.
Biomimicry is studying a leaf to invent a better solar cell, or a coral reef to make a more resilient company. The core idea is that the nature had already find solution for many of the

problems we are grappling with: energy, food production, climate control, benign chemistry, transportation, collaboration, and more. Mimicking these earth-savvy designs can help human's leapfrog to technologies that sip energy, shad material use, reject toxins, and work as a system. [7]



Figure(14) Biomimicry and the nature[27]

1. The nature as *Model*. Biomimicry is a new science that studies the nature's models and then emulates or follows inspirations from these models and processes to find solution for human's problems, example: a leaf inspired solar cell.

2. The nature as *Measure.* Biomimicry uses an ecological standard to judge the "rightness" of our innovations. After 3.8 billion years of evolution, the nature had learned: What works, what is appropriate, what lasts.

3. The nature as *Mentor*. Biomimicry is a new way of viewing and valuing the nature. It introduces an era based not on what we can extract from the natural world, but on what we can learn from it. [13]

Figure (15): Exhibition hall inspired from turtle shell [1]

Figure (16): Venus Flower Basket

and Gherkin Tower [17]

Figure (17): Armadillo Armor Connections [6]

Biology in architecture

Architecture had long been inspired by and infused with natural forms, where a building may reference a particular organic form whereas one may experience none of the physical advantages that it could lead to an innovation or extension of architectural technology.

Alternatively, a building may not allude to an individual organic form yet its function with regard to structure, mechanical or circulatory systems may be a direct result of investigations into natural basics of design and construction. This part in the paper concentrates on where the architecture develops from or utilizes the biological science that it derives inspiration from. The examples of built form outlined in the following section are presented here not because they are said to represent instances of organic or zoomorphic architecture, but because they are suitable examples of curvilinear forms whose definition is rooted in the natural geometric or organizational rules that define them**.** [13]

Figure (18): Architecture structure details inspired by the nature [26]

This newly-commissioned Garden installation by architects and engineers at the University of Stuttgart in the central courtyard of the Victoria and Albert Museum in London(fig.18)framed by red brick buildings, features a pavilion is inspired by the forewing shells of flying beetles.

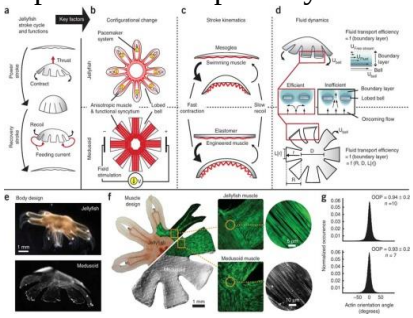


Figure (19): Architecture structure details inspired by the nature[29]

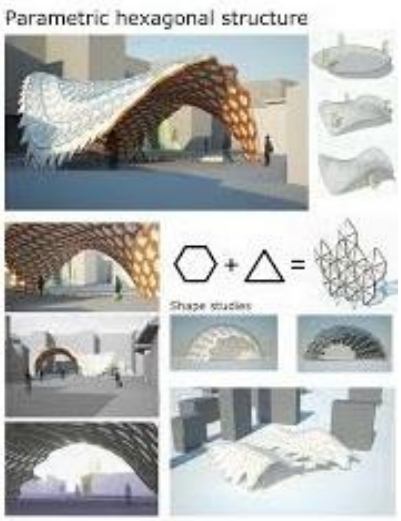
Architecture and the natural world

Figure (20): Architecture structure details inspired by the nature [22]

Throughout history, architects had looked to the nature for inspiration for building forms and methods to decoration. This section aims to show one particular aspect of ‘the nature as source paper’ that is distinct from the majority of architectural references to the natural world. The intention is to study ways of translating adaptations in biology into answers in architecture. We are entering the Ecological Age, and it is the contention of this paper that many of the lessons that we will need for this new era are to be found in the nature itself. What had been commonly called “The Industrial Revolution” but could also be referred to as ‘The Fossil Fuel Age’ maybe seen in some ways as a deflection from the kind of ingenuity that we once had in common with the nature’s evolved answers. The ubiquity and

convenience of fossil fuels had allowed extreme inefficiency to develop, and had effectively undermined resourcefulness.[12]

Figure (21): Influence of Biomimicry in architectural design [25]



Biomimetic Buildings

1. Biomimetic building would be made from local materials with little energy input.

2. Biomimetic building would be naturally ventilated and illuminated.

3. Biomimetic building would be using only current solar income instead of being connected to the electricity grid.

4. The majority of the building structure and materials would be re-usable at the end of its lifetime.

5. Landscaping would welcome animals and plants from local ecosystems and provide food for building occupants**.** [2]

Figure (22): The internal structure of a termite mound with arrows depicting the air flow as an inspiration to self - cooling buildings [6]

Termites are great builders, as evidenced by the large and intricate homes they build. Investigation of how the internal temperature stays at a comfortable level reveals that termites exploit. Fluid flow properties and create a chimney or stack effect to keep the internal air circulating. The figure shows an example of the internal structure of a termite mound with

arrows depicting the air flow and one of the inspired self-cooling buildings. This is an example of sustainable architecture. [6]

Figure (23): Learning from Termites How to Create Sustainable Buildings [16]

When the East gate building in Zimbabwe was created the goal was to reduce energy usage as to be sustainable. In Zimbabwe, where the temperature outside can vary from 3 °C up to 43 °C the air condition plays a significant role. To attain this target, Mick Pearce the architect, looked at termites and how they are able to keep the temperature in their nest within one degree. His solution was to design specially structured hooded windows, variable thickness walls and usage of light colored paints as a part of a passive-cooling structure to reduce heat absorption. By doing so East gate uses 90% less energy for ventilation than conventional building its size.[16]

Figure (24):The importance of mimicking the nature's biological and ecological systems in architecture[15]

Biomimetic Basics of form in architecture

The following forms of architectural design vary with regard to their adherence to a strict definition of biomimicry yet they share a desire to derive architectural incentive from the nature.

Figure (25): Biomimetic Basics in an architectural design [22]

1. There are basic basics that natural designs depend upon, they can be summarized as the following: [2]

a) Natural designs depend totally on natural sources, and diversity of possibilities.Among all sources, Sunlight had a special importance.

b) Natural designs depends upon total recycling, where waste of a species is food for another, symbiotic relationships helps achieving the zero waste concept.

c) Natural designs respect the environmental limits. According to this respect, natural designs also adjust to the here and now, in another word, they requires local expertise.

d) Natural designs use only the necessary resources, and avoid overbuilding.

e) Natural designs use the functional form and depend on fractal design where beauty hides, and the designmayextend without planning ahead.

f) Natural designs depend upon network creation instead of linearity and rely upon swarm intelligence.

2. The levels of biomimicry can be classified into: [2]

a. Three general levels:
1) Form or Structure level
2) Behaving or process level
3) Ecosystem level.
b. Nine Architectural levels:
1) Concept
2) Process
3) Morphology
4) Form
5) Structure.
6) Skin.
7) Material.
8) Expression.
9) Symbolism

Biomimicry application in Architecture design

Biomimicry design is not only adapting the design from the the nature but also considering how to use the nature's effective functions such as heating and cooling system, protecting natural light and ventilation.

Figure (26): Architecture form inspired by the nature [34]

Another example of Biomimicry is looking like a strange sort of man-made volcano, the All-Seasons Tent Tower.

Figure (27): Tent tower [17]

Architecture is a multi-function cylindrical tower powered with solar energy and covered in a mesh skin that filters sunlight for temperature regulation. As the city of yerevan is locatd in a region famous for being subjected to earthquakes, the main driver when deciding on a suitable structural system for the building was safety during earthquakes.

The vertical structure, which resists gravity load and forces resulting from earthquake action,

was rationalized to reinforce the tower's concrete cores and composite columns. Special care had been taken to optimize environmental conditions and minimize the energy demands of the tower.

The external facades will have a high performance skin with an adaptable external shading device to reduce solar gains in the summer. An embedded pipe and concrete slab would provide cooling without draft problems and in winter comfortable heating. In the summer, the cooling of internal spaces is achieved primarily through the use of the slab system. In winter, the fresh air will be warmed inside the units and distributed into the rooms using the concept of displacement ventilation. [17]

There are very few urban development plans that address housing the inevitable wave of displaced people that could arise as oceans swell under global warming. Certainly none are spectacular as this one. Vincent Callebaut proposed The Lilypad, which is a concept for a totally self sufficient floating city intended to provide shelter for future climate change. [17]

Figure (28): Lily pad, a floating city [17]

Examples of Biomimicry in different aspects and in architecture

These are just some examples of the nature's designs. There are many more that had already been discovered and millions of more with their secrets waiting to be unlocked**.** [31]

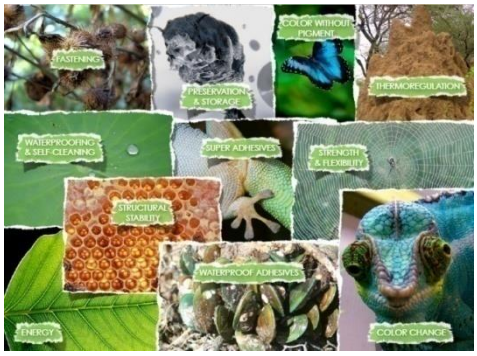


Figure (29): Biomimicry in general [6]

***Transportation*: Learning from Kingfishers**

Figure (30): Biomimicry in transportation [16]

***Energy*: Learning from Humpback Whales how to create efficient Wind Power**

Figure (31): Biomimicry in energy [16]

***Energy Efficiency*: Learning from The nature how to create flow without friction.**

A company named PAX Scientific Inc. was able to reduce energy usage by 10-85% in conventional rotors and noise by up to 75% when applying The natures model to fans, mixers, propellers, turbines and pumps after looking into how The nature moves water and air. [16]

***Medicine*: Learning from Chimpanzees how to heal ourselves.**

Figure (32): Biomimicry in medicine [16]

***Industrial Design*: Learning from Trees and Bones how to optimize Strength and materials.**

Figure (33): Biomimicry in industrial design[16]

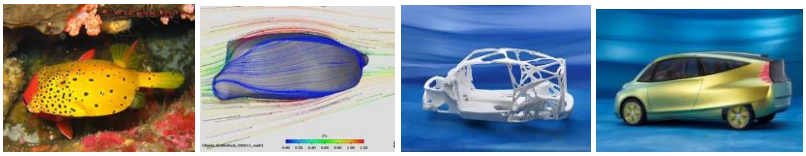


Figure (34): Structure inspired by the box fish and tree growth patterns [10]

Architecture: Learning from termites how to create Sustainable Buildings.

Biomimicry in architecture:

Figure (35): Minister of Municipal Affairs and Agriculture office in Qatar. [28]

The sunshades on the building had the ability to automatically fluctuate up and down, depending on the desired interior temperature, to regulate the amount of sunlight and heat that is transferred into the space. This innovative solution allows this building to lower the size and amount of artificial cooling necessary for the building to operate properly as well as providing a sustainable solution that is aesthetically pleasing. At the base of the building is a botanical garden which will hopefully be used as an edible garden and living machine.
Overall the building is an example of a solution at the macro level, encompassing the building as a whole and how it functions within a specific environment. [11]

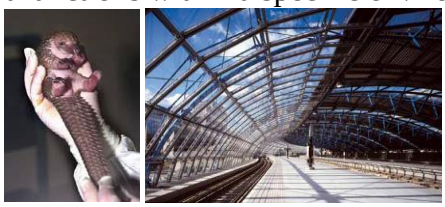


Figure (36): Nicholas Grimshaw & Partners' Waterloo International Terminal and the pangolin [10]

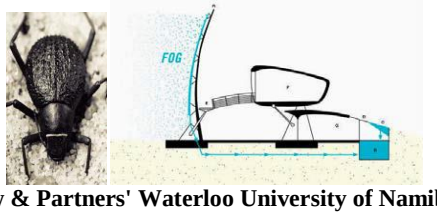


Figure (37): Nicholas Grimshaw & Partners' Waterloo University of Namibia and the stenocara beetle [10]

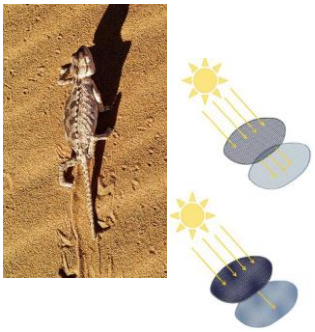


Figure (38) Adaptive Glass [11] Mimicking Namaqua Chameleon[32]

One of the earliest examples of Biomimicry was the study of birds which enabled human's to gain the technology of flight. Though, it could be argued that our ancestors mimicked the techniques of the animals around them to become more successful hunters or gatherers, or to create better shelter. Sustainable development is moving to a new level where buildings are integral to the nature, supporting the nature's work rather than interfering with life-sustaining ecosystems. The nature had been offering immense ideas and inspirations to designers for creating architecture. [17]

Figure (39):Bird's Nest stadium [17]

The National Aquatic Center in Beijing, China structure stands on enormous twisted beams around the exterior similar to a nest. The designing team studied some countless natural nests for understanding the weaving pattern of the threads. Some hundreds of models were created for the design. [33]

One of the most effective ways to cut down the ecological footprint of buildings is to follow the lead of the nature through biomimicry. The Habitat building envisioned for china is a future forward example of biomimetic architecture that fuses high-tech ideas with basic cellular functions to create 'living' structures that operate like natural organisms. This the nature-inspired method to city living looks at the urban landscape as a dynamic and ever-evolving ecosystem. [17]

Figure (40):Habitat2020, china[17]

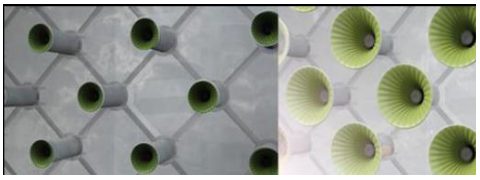


Figure (41):Living skin of Habitat2020 [17]

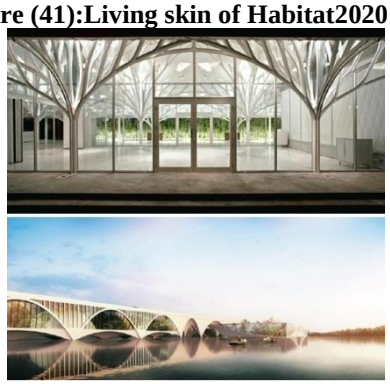


Figure (42): An example of organic inspired Architecture structure[30]

Conclusion:

Biomimicry as an innovation can be considered as following:

- Process
- Way of thinking
- Inspiration
- Multi-Level
- Basics
- Model
- Measure
- Mentor
- Sustainable Development
- Method
- Method

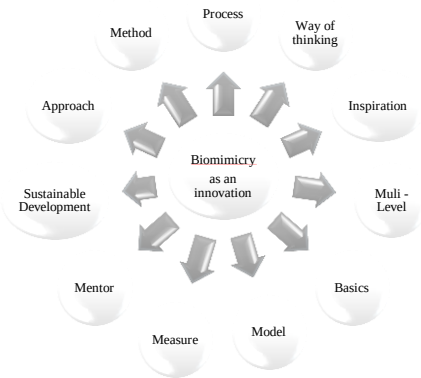


Figure (43): Conclusion diagram

Results:

1- Biomimicry as a method brings into view a method for design thinking that includes the possibility of creating buildings inspired by the nature.

2- Biomimicry provides a path to conceive buildings that are aesthetically, materially, and mechanically more advanced in terms of the environment and sustainable technologies.

3- Biomimicry as a method or system is intended to stimulate the designer into thinking about new materials and environmental resources from the perspective of science and how such data may factor into the visualization and creative process.

Recommendations:

1- Designers can develop this method looking to and from the nature in partnership with current and evolving design practice or in experimental design-science.

2- Biomimicry can be used to rethink industrial products, and for producing biomimetic architecture that is better functioning and less toxic products, infrastructure, buildings, and ultimately cities.

3-Designers need to understand the nature and how enlightened thinking can help us learn and live in harmony with the nature.

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