PalArch's Journal of Archaeology of Egypt / Egyptology

Biomimicry in Architecture- A Mindful Imitation of Nature

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Sreepriya Jayakumar, Suprabha K R: Corporate Sustainability Reporting And Firm Performance Linkage-A Literature Review Approach -- Palarch's Journal Of Archaeology Of Egypt/Egyptology 17(9). ISSN 1567-214x

Keywords: Biomimicry, Biomimetic principles, Biomimetic materials, Sustainable buildings

ABSTRACT

The imitation of nature is a strategy to live and to push towards a sustainable future for mankind. This research analyzes the 9 principles of biomimicry and its adaptation to the existing human technologies to create a comfortable environment in a challenging situation. Situations such as pollution, traffic congestion, water scarcity, and climate change. Although we do not have the solution to overcome all of these problems, architects still can control the impact of some of them with the design. The process that deals with environmental sustainability and energy conservation, which involves architecture, is something that cannot be disrupted and that brings researchers and architects before the complexities of science and design where specific studies and trials must be conducted on materials and its application on the structure and design of buildings. The advancement of technology with the creation of new materials and construction methods has made it easier for architects to imitate nature more effectively. The primary goal of this research is to increase awareness among architects of the biomimetic strategies used in the built environment. The field of biomimetic research is progressively growing and extremely promising. Hypothetically, this report introduces in each case study an empirical method founded on "Bayesian networks" to check the immediate outcome of the biomimetic structure according to specific criteria. By providing a built environment that allows people to live and function more efficiently, we can transform it into a new and sustainable man-made environment.

1. Introduction

Energy shortages and elevated energy consumption in houses have been a significant issue globally since 1970. There is a growing need for interventions that will help enhance the use of alternative energy in the built environment. Meanwhile, methods inspired by nature have appeared as a fresh approach to achieving indoor thermal comfort. Nevertheless, in order to apply these strategies in the design and development of the built environment, one should have a good understanding of the ecosystem. Biomimicry is the study that deals with the imitations of nature in order to find innovative solutions to man-made problems, by investigating nature's design, frameworks, and procedures. This paper focuses on analyzing the design process that nature and architects adopt to overcome challenges.

Biomimicry is far more than just replicating a natural object or structure. It is not just about creating something that is considered to be green and environmentally friendly. It is first a near examination of an organism or ecosystem, then a careful implementation of the fundamental design values discovered in the real environment. A researcher at the University of Acron and Biomimicry Research and Innovation Centre, Peter Niewiarowski, said "The way biological systems solve problems is pretty different from the way engineered systems solve problems, human-designed solutions, are crude and additive" [1]. They are more reliant on resources and energy to speed up reactions that are both costly. Natural procedures, however, depend on the distinctive design and material properties.

Over the centuries, nature has changed and acquired incredibly advanced strategies for overcoming major issues [2]. The environment around us offers good instances of functional structures made with a limited amount of materials. Many of these strategies could have influenced people to accomplish exceptional results. The design of fishing nets, for instance, might have derived from a spider web, and the lightweight structures used in airplanes and other structures may have been originated from the durability and stability of honeycombs. While biomimetic research has become prominent over the years, the idea of it was present long before. People have been taking inspiration from nature in order to create new materials and inventions ever since the Chinese tried to make artificial silk more than 3,000 years ago.

The practical use of biomimicry is now recognized as a feasible strategy to help resolve environmental issues. Biomimicry 3.8, Missoula and HOK, two major architectural firms formed an alliance in 2008, to integrate biomimicry in their design process. This collaboration is worth mentioning because of the prestige of HOK developers as green pioneers who helped establish the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) certification system [3]. The acceptance of biomimicry by HOK is transformative and that by itself will spread the idea around the world. Architects have effectively combined the principle of biomimicry and architecture to generate an ideal environment.

This research focuses primarily on the implementation and features of bio-based materials as well as the principle of biomimicry. Biomimicry is an important means to achieve sustainable architectural design and development.

The present research is an effort to create a thorough assessment of case studies to investigate how biomimicry has been an alternative in the modern world to solve a large number of design issues that infuse the rising sciences with techniques that have been tested through time, of creating more sustainable and restorative architecture.

The research is based on secondary sources. Therefore, most of the references are secondary places and could not be visited.

The first part of the paper explores the historical origins along with key sources of inspiration and the way nature has influenced architecture in the past. The second section is to review the biomimetic principles and various methods by which they can be applied to architecture and to understand the purpose that architects have developed for the influence of nature in their design.

The third part of this research will investigate four case studies of built structure that used biomimicry in its design: A hive-like double-skinned façade made of Elegant Embellishments' Prosolve 370e modules, a natural soap bubble structure adapted into an architectural form with the help of surface technology, a facade, based on biology analogy of the tropical durian fruit , and a temple inspired conceptually by the lotus flower.

Mimicking the natural world is an efficient method for creative design. It was not until recent years that biomimicry has been officially integrated into architectural design. Only a handful of industries use biomimicry in their design processes.

New findings are made in the field of biology every day, and architects should take advantage of these discoveries. When designers make the effort to "biologize" and learn and observe how nature works, they will be enlightened and spurred to design a built environment that functions like nature [4]. The objective here is not to try and replicate nature but to get inspired and learn from it and use its principles to create efficient designs.

2. Historical background of Biomimicry

One of Biomimicry's earliest examples was the study of birds that helped people to get the flight innovation. Leonardo da Vinci, Frank Lloyd Wright, Fri otto, and Antonio Gaudi are all examples of early practitioners of biomimicry. However, these were individual instances not the beginning of a sequence. Sustainable development is moving towards a new stage where buildings are an integral part of nature, promoting the work of nature rather than interference with life-sustaining ecosystems. The way we design our buildings and cities is essential to the sustainability of society, the environment and the economy. However, sustainable development has become more challenging.

Nature has offered immense ideas and inspiration to architectural designers. Dayna Baumeister, a professor at Arizona State University and co-writer of the biomimicry book, illustrated the concept that nature has resolved many problems which we face today and how this can be used to design. Through analysis, these designs could be imitated by the three levels of biomimicry architects. To understand nature's design, we must understand the three levels of biomimicry: nature as a model, nature as a measure and nature as a mentor.

In 1982, Otto Schmidt coined the word biomimetic and in 1997, Janine Benyus, an Innovation Advisor and co-founder of the Biomimicry Institute, rediscovered this word. Sometimes the notion of biomimicry is misinterpreted as structures that appear like natural organisms, That is to say, shell-shaped structures, which is another distinct strategy in a design called Biomorphology. The imitation of natural structures or methods will influence the shape, but that is not the basic concept of biomimicry. Biomimetic, therefore, is not a straightforward imitation of nature, nor in matter and function nor in artistic terms, but an understanding of nature's principles to help understand similar, technological issues that would then be resolved by means of the implementation of integrated techniques. The architect has an abundance of living nature to discover, but one should be careful not to interpret it too directly. Nature's inspiration to architecture won't work if architects don't follow the intermediate stage of abstraction. Application of biomimetic is then a 3-step process: Research – Abstraction – Implementation. Initially, the design method relies on biologists' and scientists 'understanding rather than human design issues. The designer defines a relevant feature from the environment that is abstracted before it is identified and converted into a technological context

Salma 's study of biomimicry shows that it is one of the sustainable design tools Salma believes that the feedback schemes in nature for the design method are strongly interlinked and influenced by the environment and are far more evolving in terms of environmental and sustainable output [5]. Guild has identified that the design method contains two categories of biomimicry: Define a need or design issue for human beings and see how other organisms or ecosystems resolve the issue. Design that looks at nature and identifies or translates into human design the specific characteristics, actions and function of an organism or an ecosystem, is known as biology defining the design [6]. Maibritt divided the study into three different imitation levels: organism, behavior level and the level of the ecosystem [7]. A Research of overlaps in biology and architecture demonstrates that Grubber has been effective in transferring the principles of nature into architecture in creative opportunities for architecture alternatives.

In the adaptation of biomimicry in building form, innovative products or real advances in the form of a ' truly biomimetic ' construction is still lacking '[8]. This means that biomimetics may be seen as architectural styles and that define the whole of a building that best reflects in its overall form. According to Menges Evolutionary and physical limitations restrict the process of the nonlinear design method. , the difficulty in addressing this strategy resides in the interrelation and mutual effect of materials and the changing environment.

The purpose of this research is to study biomimicry for the use of natural alternatives to man-made problems.

3. Biomimetic principles

Three levels can be identified from the adaptive solutions of nature:

A. Organisms level-

The solution to specific issues that imitate the functionality of certain species is needed, irrespective of the context in which they exist. Instead of a significant alteration, the idea is to integrate technology into structures.

B. Processes level

It's a question of finding alternatives that change the environment, explore interaction patterns and include them in the design of buildings.

C. Ecosystems level

In this situation, architecture and the built environment should be an aspect of a vast ecosystem that participates in the various cycles of the ecosystem.

Fig 1. Levels of biomimicry [1]

of organisms, for this is its most primary application. Its real ability, however, is not only to include specific techniques but underlying principles that in turn leads to not only sustainable but renewable solutions. The aim is to improve the efficiency and sustainability of building skins while implementing biological principles from the initial design stage as obligatory requirements, which can be found in organisms, processes and natural systems. As a result, the number of design requirements increases but also acts as a guide to seeking ideal solutions at different stages.

4. Characteristics of Biomimetic Architecture

As to the principles on which organisms and natural systems are formed, there are a set of characteristics that are most commonly acknowledged in biological systems.

A. Openness/exchange with the environment

All life forms interact with their environment by interchanging data, matter, and energy; locally integrating, exploiting and improving simultaneous cyclic procedures, and creating relationships of cooperation and competition. These principles can be used to encourage the use of available local resources in the area, using locally accessible renewable energies with a "cradle to cradle" strategy, taking into account the entire life cycle of products and systems or as selection criteria in the use of materials: recycled and/or recyclable, non-polluting, biodegradable.

B. Resource management / optimality

The optimization of materials available characterizes organisms and natural habitats. According to principles such as multifunctionality, entropy growth or nullity, specific construction with little resources or alteration of form to function. The use of embedded functional components and structures could thus be encouraged not by the amount of material, but by-products with low energy, renewable, and energy-efficient sources or shapes.

C. Order / structure / growth

In the context of living organisms, the principles of self-organization, which are evolving from easy components and laws towards higher complexity, characterize themselves by being progressively complex systems ; integrity through self-renouvelation and regeneration or building systems bottom-up based on nested components, In reality, we could use self-reinforcing materials and systems, production and production systems by means of additive reinforcement or systems that have been entirely optimized rather than forming individual components. In other words, this means we could use individual components.

D. Adaptability

The primary feature of living systems is their capacity, owing to their elevated resilience and integrating variety, redundancy and decentralization requirements, to adapt to varying circumstances. It could be suggested, for instance, that the decentralized multi-nodal control systems are used to lower the likelihood of failure, improve risk management and increase the resilience to unexpected situations and change external circumstances.

5. Different approaches for applying Biomimicry in design:

Biomimicry provides fresh and inspiring alternatives in the field of architecture and engineering, while at the same time providing opportunities for sustainable development in the built environment. Researchers have developed two primary methods, a problem-based approach and a solution-based approach to biomimicry design.

A. The problem-based approach (Design to biology):

This method is guided by nature's influence through progression of either irregular or dynamic steps. This offers guidance and in-loop refining. By identifying the problem, the designers are seeking solutions to that approach. This leads researchers to match the question with an organism that has solved a similar problem. The problem-based approach is based on target identification and design constraints.

B. The solution-based approach (Biology to design):

This method has different names such as the design of the biological influence, the bottom-up approach and the biologically influenced design driven by the solution.

This strategy is utilized when the design process is based primarily on biologists and researchers' scientific expertise, rather than on human design issues. For example, the scientific examination of the lotus flower has resulted in many new designs, which keeps its surface clean from the swamp.This includes the STO Lotusan that enables a building to self-clean.

Table 1: Two types of approaches for applying Biomimicry in design [10]

Problem Based Approach	Solution based Approach
Step 1: problem definition	Step 1: biological solution
Step 2: reframe the problem	Step 2: define the biological solution
Step 3: biological solution search	Step 3: principle extraction
Step 4: define the biological solution	Step 4: reframe the solution
Step 5: principle extraction	Step 5: problem search
Step 6: principle application	Step 6: problem definition
	Step 7: principle application

6. Bio-Inspired Materials

Nature designs are elegant, biodegradable and long lasting, but the tricky part seems to be recreating most of these materials for our own purposes. Biomimetic materials are intended to replicate more than one feature of the material created by living organisms. This attempt at description illustrates a common feature of biomimetic materials and biomaterials, as effective biomaterials either serve: (1) restore a natural role in the absence or inability of the original material to perform its function; or (2) preserve an ideal environment for processes such as cell culture, tissue growth, biomolecular testing, and biotechnology.

A. Classification of Bio-Inspired materials:

Bio-inspired materials used in buildings that fall into four major categories : (1) the use of natural materials in the production process for better recycling and imitation (2) structural properties, (3) functions, and (4) biological processes of natural organisms.

Bio-inspired materials for recycling can be divided into two main categories: (1)bioplastics and (2) biocomposites. Bio-inspired materials that imitate organisms micro/macrostructure or patterns show either (1) load-bearing behavior or (2) thermal behavior. Imitating organisms function has inspired materials with (1) intelligent response mechanism known as smart materials used primarily for the purpose of movement or heat control, self-cleaning, self-healing and vibration resistance; and (2) waterproofing or water harvesting mechanism. Bio-inspired materials that mimic biology can be divided into two interlinked and practically similar classifications: (1) growing and (2) reproductive materials.

Biomimicry mainly focuses on the micro- and macro scale levels of imitation. Nanotechnology could also be seen as a kind of biomimetic design strategy that focuses on impersonation on a nanoscale. For example, Crystallizing imitation of natural materials such as skeletal mineralization, Bio-inspired concrete was designed by the researchers to modify the physical and chemical properties of concretes nanostructures Nanotechnology in design adds value mainly to the functionality and the efficiency of conventional materials and turns them into more efficient products such as self-cleaning windows, UV-resistant timber frames, or dirt-repellent coatings.

B. Functions of Biomaterials in Buildings

Facades are generally related to resilience and strength when forced to deal with extreme weather conditions.. Although, in some situations, biomaterials used in facades are less stable than non-biomaterials. Nevertheless, if correctly designed, biomaterial façades can be at least as resilient as non-bio-based façades.

Biomaterials perform different functions in buildings. For instance, Timber components form not only a load-bearing structure but it also acts as a facade that protects the internal environment from the external conditions Biomaterials also have a significant esthetic role, which the building users value greatly. Biomaterials should be safe and adaptable to people's needs when carrying out various functions.

The distinct characteristics and the natural beauty of biobased materials are particularly desirable in different usages, including the design of the interior and exterior of a building. Due to their renewability and cascade use, the major benefit of biomaterials is their minor effect on the environment. Biomaterials allow prefabrication and rapid assembly. Because of a desirable weight-to-load-bearing ratio, they allow high rise buildings to be built while allowing significant liberty in its design.

7. Challenges in Bio-mimetic Architecture

During the exploratory phase of the research, one important limitation was recognized. There is a considerable gap between biomimicry (focusing on the environment) and architecture (focusing on structures created by humans). Biomimicry is a natural evolution process whereas architecture creates a built environment. This limits both biologists and architects 'the availability of cross-domain Information. This has actually been recognized as one of the main constraints on the applicability of biomimicry to architecture. Biomimetic techniques have been alleged to be more relevant in mechanical engineering than in architecture. The level of development and its ability for mass production allow research ventures to be more appealing in biomimetic approaches. Because projects differ in customer, user and context, scale and complexity, construction designs can be hard to replicate in a similar manner. The limitation of biomimicry in architectural practices has been identified as one of its main drawbacks.

8. Case Study And Analysis Of Biomimetic Buildings

A. Manuel Gea González Hospital in Mexico City

More than 8 million people live in the central area of Mexico City. In 1992, Mexico City was singled out as the most polluted megacity in the world. It came just ahead of São Paulo in a World Health Organization (WHO) and UN Environment Programme (UNEP) study of ‘Air Quality in 20 Megacities’ [11]. The air quality of Mexico was outstanding for only 9 days in 1992. With a series of interventions, 248 days of good air quality were recorded in 2012. Traffic is prohibited on particular days in order to lower carbon emissions from vehicles. Since the public vehicle fleet is old, however, these interventions prove to be inadequate and environmental alarms often go off.

Architect Manuel Villagrán designed the original Manuel Gea González Hospital and finished it in 1942. A new clinical specialty tower, for which environmental factors were taken into consideration, was constructed in 2013 after years of service. Manuel Gea Gonzalez Hospital is not only used to aid the sick people of Mexico City but it also benefits the environment with its new facade. A hive-like double-skinned facade made of Elegant Embellishments' prosolve 370e modules has been installed to help clean up the city’s polluted air. The functional and artsy decorative facade helps absorb the toxic air surrounding the hospital and improves the quality of life.

Fig. 2. Façade of Torre de Especialidades [12]

The main aim of the project was to add to the pollution control measures in Mexico City that help in improving the air quality in the city. In an attempt to lower the air pollution in the immediate vicinity of mono nitrogen oxides (NOx), organic compounds (VOCs) and sulfur dioxide, the façade of the Manuel Gea González Hospital were created.

Fig .3. Installation of the prosolve tiles [13]

A new tile type called proSolve370e is used on the façade of the hospital building. The tile can neutralize toxins generated daily by 8,750 vehicles according to its innovators, the Berlin-based design company Elegant Embellishments. The winding form of the façade enhances the active surface area that will help to neutralize light, air turbulence, and pollution.

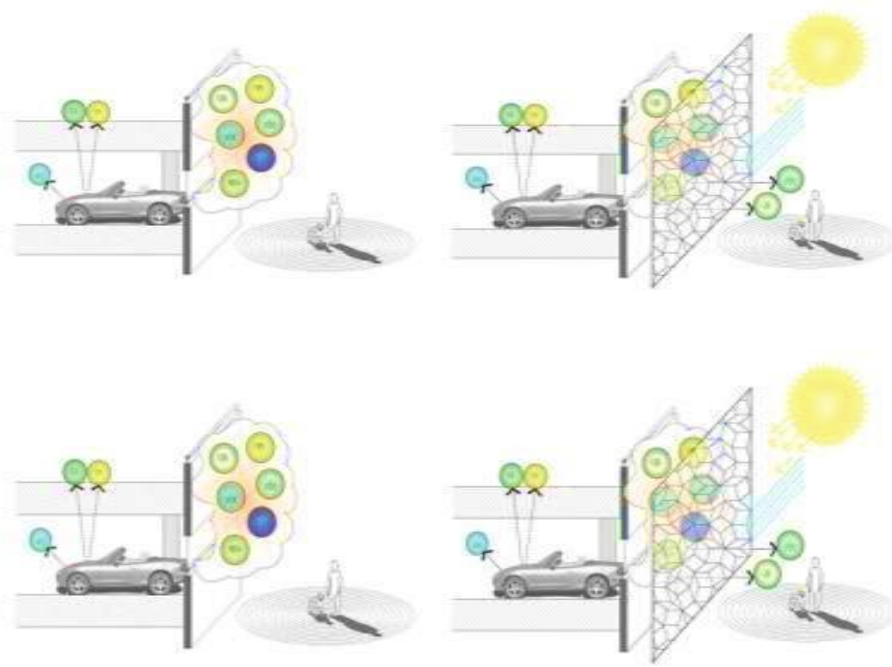

Fig. 4. Working of the prosolve tiles [13]

Inspired by quasicrystal patterns, the winding façade creates a white geometric shade covering the front part of the hospital. Prosolve has been designed to decorate the double-layered facade and it was selected for its anti-microbial and de-pollutant characteristics, which also create a wonderful design statement. Prosolve tiles are covered with superfine titanium dioxide which, when triggered by daylight atmosphere, fights pollution. The tiles help neutralize pollution as well as other toxic substances present in the atmosphere when installing near heavy traffic or in building façades. An assembly of these tiles helps not only to improve the quality of air in the building but also the air in the city.

The issue of smog in Mexico city is targeted and solved by the construction and materials used for the Manuel Gea Gonzalez Hospital Specialty Tower in Mexico. Its structural composition helps to improve the quality of air by neutralizing the pollutants. The façade of Manuel Gea Gonzalèz Hospital in Mexico City is the first major project of this kind.

The shape of the facade is not only visually appealing but also functional, it helps to protect the patients inside and to optimize the impact of the finish. The shape of the facade was derived from omnidirectional corals that absorb the sunlight falling on the ocean surface due to its large surface area. The facade is made up of a form that is omnidirectional and allows surface expansion in order to improve technical efficiency. From any direction, it can receive pollutants and sunlight. The irregular shape of the facade creates turbulences that slow down the wind speed so that the pollutants can be absorbed by the facade with ease.

Using Prosolve can help improve the air quality and based on the layout you can enhance its efficiency as well. This design and material are not limited to outdoor applications, but can also be used inside as well in order to enhance the air quality in the areas where it is used. More interestingly, the prosolve modules are capable of absorbing smog in the atmosphere for nearly a year or at least until its coating wears off, during this phase the pigment remains unaltered. The prosolve tiles of the façade have the potential to neutralize the level of toxins that are generated by 1,000 cars a day in Mexico City.

The design process was important as it resulted in the breakage between conventional approaches of the industry. Even though the hospital doesn't look anything like a futuristic building it still reflects a living type of architecture As an outcome, the following should be included in future buildings:

1. Human- environment interaction.

2. Express climate and culture.

3. façades must convey orientation

The visually dynamic façade helps people to be aware of the pollution and the technology used in the facade to mitigate it. This facade has parasitic characteristics so that, when used along with trees it can help to make the environment better while waiting for good clean energy transport to be created.

9. National Aquatics Centre

Between 2004 and 2007, the water cube was primarily built for the 2008 Olympics, also known as the national Aquatic center. Chriss Boss, Tristam Carfrae, PTW Architects, CSCEC, CCDL, and Arup, built the 4 stories high building. The National Aquatic Centre, built during the 2008 Beijing Olympic Games, is one of the most dramatic and interesting sports venues. The idea combines the square, that symbolizes Chinese culture and natural soap bubble structure adapted into an architectural form.

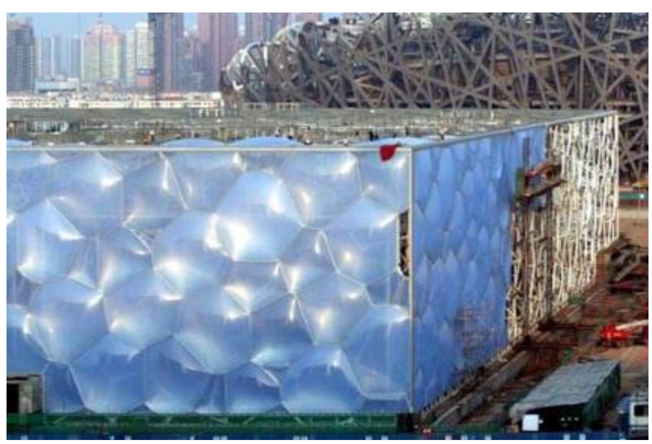

Fig 5. The national aquatic center, Beijing [14]

In addition to offering a multipurpose aquatic center, the objective was to build with comprehensive use of digital technology, energy-saving, and water-conserving techniques, as well as integrating new building materials.

Fig. 6. Interior of the national aquatic center[15]

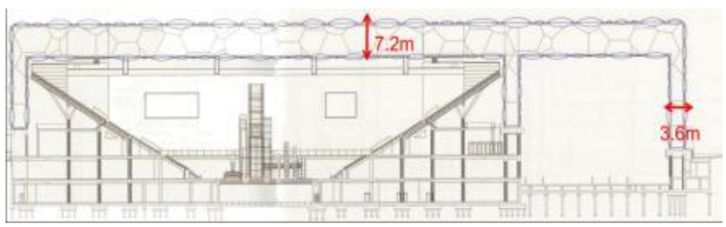

Fig 7. Sectional elevation of the aquatic center [15]

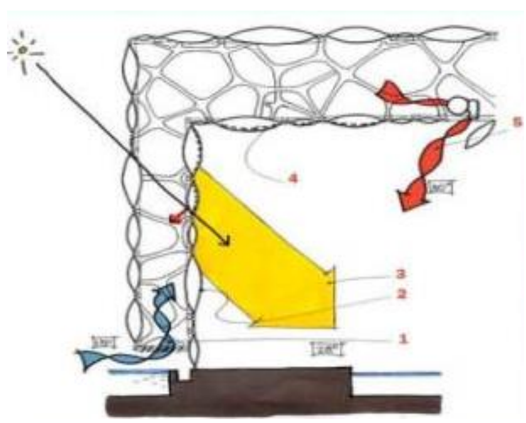

Fig 8. Sketch of the water cube [16]

The answer to most complex problems was an insulated greenhouse based on previous understanding. The primary steel framework in a cavity, separated from the exterior as well as a corrosive pool environment, with diffused natural light.it was even agreed that ETFE covering would be a better and effective means of construction – because of the Use of limited material and eliminate secondary structure requirements, while offering greater insulation than single glazing.

The design of the Water Cubes is based on water bubbles in the foam, and although it may appear arbitrary, its design is inferred from geometry and crystalline systems principles. The construction of the building consists of a steel frame whereas the bubbles are made of 0.2 mm-thick ETFE (Tetrafluoroethylene ethylene) pillows. In comparison to traditional glass, the membrane, apart from letting in more light it also lets you heat up all five pools, reducing energy costs by 30%. Efficient filtration and backwash systems retrieve and recycle rainwater from the roof, and an unprecedented LED lighting mechanism transforms the Water Cube into an incredible nighttime kaleidoscope. The building is best suited to deal with the seismic conditions in Beijing, although delicate in appearance, it undoubtedly is the most seismically resistant structure in the whole of China.

The architect of a water cube, Tristan Carfrae, learned that earlier, scientists like Lord Kelvin noticed in the early 19th century, that the tetrakaidecahedron, a shape that enables a surface to be divided into equal-sized cells with minimum space in between them. Plateau, a Belgian physicist, examined the characteristics of a soap bubble and how its three sides connect creating a line in between. The thin layer of liquid in soap bubbles are capable of reducing surface area and surface heat. It answered Kelvin's question at the same time because the surface tension of the divisions decreases the size of the bubble [17]. The geometry was found to be the most effective means by which the space was subdivided. Although the geometric form is strictly regular, it seems totally natural and organic when seen from different angles. The facade of the building provides a transparent quality of water with the help of the bubble structure. By effect, the people inside and outside the building are able to experience water

The bubble structure is a true spatial framework in which all the elements are formed within the nodes. In a country that faces a lot of seismic activity this structure may be impractical but a place like Beijing that experiences a lot of earthquakes, this structure proves to be efficient as it is an ideal energy absorptive structure. To facilitate the production process, the designers built the structure from simple circular tubes fused to spherical nodes on each end.

The Water Cube accomplished many environmental results that contributed to the achievement of an energy-efficient building and by using a biomimetic approach to resolve all the problems and objectives

The outcomes include:

- 30% decrease in the energy cost
- 55% decrease in the use of artificial lighting
- Greenhouse design
- The building provides the experience of the transparent quality of water
- Rainwater is harvested and reused with the help of efficient filtration.
- The energy saved by the ETFE(Ethylene

- tetrafluoroethylene) facade is similar to that of covering the whole roof with solar panels.
- 20% of solar energy is used for heating purposes

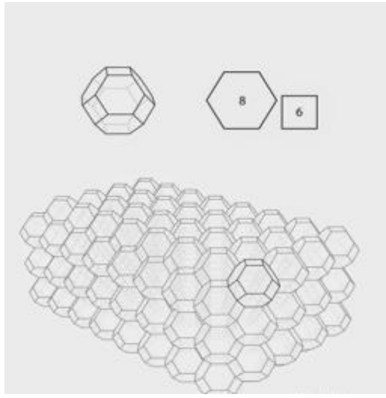

Fig 9. Kelvins structure [18]

In the look for a geometric shape, the water cube used biomimicry to find a form that increases the surface area in a 3-dimensional space and allowed efficient energy consumption in this design, there are many concepts derived from biomimicry such as:

1. Experience of nature within the environment

2. Facades are supposed to convey orientation

3. Designing an adaptable and comfortable environment

4. Significance of natural forms and geometry

C. The Esplanade Theatre

With the goal of making Singapore the cultural capital of Asia, the government held an international competition in 1992 to select the Esplanade theatre project, a cultural centre made up of four theatres and a concert hall.

Esplanade is among the most luxurious and well run reservoirs in the world on the coast of Marina Bay in Singapore. It comprises a concert hall that can seat 1,600 guests and a theatre capable of handling up to 2,000 viewers. In addition to hundreds of exhibition halls , Esplanade also has a library, a trade centre, and restaurants. The center is a two-storey structure designed by Micheal Wilford, DP architects.James Stirling and Michael Wilford won the competition. After Stirling's death , Wilford took over the project with the DP Architects.

Fig 10. The Esplanade Theatre, Singapore [19]

The architects' vision was to build a center of versatile rooms for the broad range of scenic styles in the East and West as per the multi-ethnic community of Singapore.

The goal was to create a design that reflects past and future works and to blend the latest innovative technology with local culture.

This inspired the building's design with its two major crowds (the auditorium and the opera house) and shells of sea urchins .It is also correlated to the durian fruit , an Asian fruit consisting of yellow and spiny shells.Since the original design has been dismissed for using so much glass and the design relevant to west architecture, the choice was made to adopt the Biomimetic solution. The design was also criticised for being inappropriate to Singapore's tropical climate. The new design therefore seeks to create a center that acknowledges its culture and environment, without seeming too conventional.

Fig 11. The Esplanade Theatre, Singapore [19]

In an attempt to address the public problems, the sun shades were inspired by the spikes of the durian fruit to avoid overexposure to the sun. The spikes serve as a defensive barrier to the fruit and as sun shades of the Esplanade Theater. The sunshades are created from aluminium. The form provides a feeling of tranquilly and is common in certain conventional Asian cultures. The eastern and the western facades have the longest sunshades with the greatest sun and heat. Whereas the façades in the North and South are smaller.

Fig 12. View of the Esplanade Theatre from marina bay [19]

Natural materials such as timber and stone have been used in many parts of the theatre and Much of the floors have been paved with stones.The interior walls are built with sandstone. The rooms are constructed from reinforced concrete inorder to attain acoustic perfectionThe sunshades are made of insulated glass with aluminum installations cornering the in-between points.

Outcomes:

There have been several positive benefits that have resulted from the theatre.

- Comfortable environment for the users
- Protection from the heat of Singapore
- lets daylight to penetrate, but prevents the inside from excessive heat.
- decrease in the use of HVAC
- 30% decrease in the energy cost
- 45% decrease in the usage of artificial lighting
- Maximizes natural ventilation

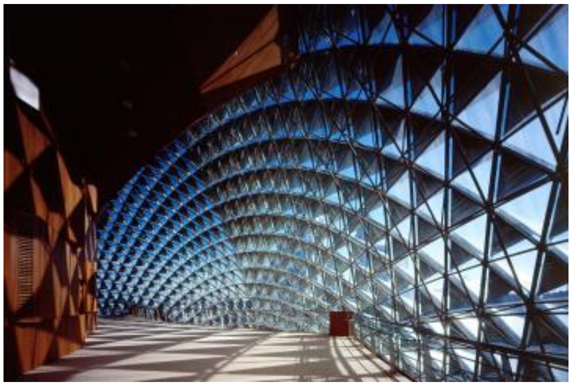

Fig 13. Interior of the Esplanade Theatre [20]

These compact, streamlined space frames equipped with triangular glass and a series of champagne-colored sun shades that give an ideal balance between sun shading and outdoor scenic views. The outcome creates a dramatical play of shadows and form all day long; at night the structure lights up like a lantern across the bay area.

D. **The Lotus Temple**

There is no idol and people of all religions, cast and beliefs are well received. This is the impression of the lotus temple [21]. The lotus temple, that imitates the lotus flower , is visited by more than 10,000 visitors every day.The Lotus Temple was built in 1986, in the outskirts of Delhi, and resembles a Bahai House of Culture. The beautiful structure was designed by architect Fariborz Sahba who was proposed in 1976 for the design of the Temple.

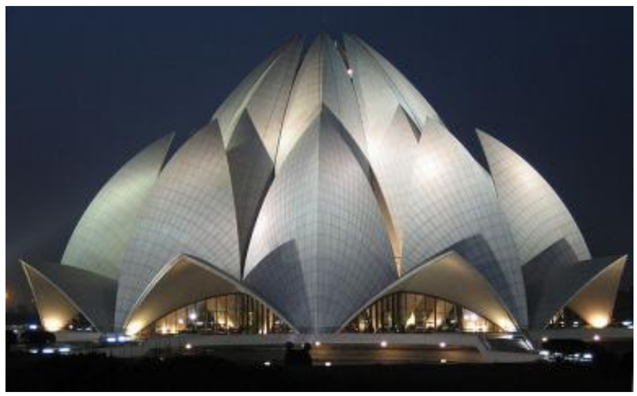

Fig 14. The Lotus Temple [21]

If we perceive Hindu architecture, all of them display unique, sacred symbols common to all Indian religions despite the apparent variations between the different temples. such symbols have been used in various countries and religions around the world.The lotus flower is one of these symbols.Ar Fariborz Sahba designed the temple to mimic the lotus flower that signifies purity and prosperity in the Hindu tradition.This concept was then translated into specific geometrical forms like circles and cube that have been then converted into algorithms and used as a foundation for the structural analyses and technical plans . The outcome was an intricate geometrical form that took nearly two years to complete.

The design has 27 'petals' with marble cladding grouped in three- to nine-sided clusters.These 3 petals, each with a pool, were symmetrically aligned and repeated at regular intervals, forming a sense of rhythm. The Nine pools that encircle the temple,helps in not only improving its charm, but also serves a part in keeping the interior of the temple cool.

Fig 15. The Lotus Temple [22]

All components are in multiples of 9, which depicts understanding, harmony and peace.

The plan is made up of circles and circular segments, the repetitive trends gives a sense of rhythm and allow us to predict what is going to take place next.

Fig 16. Construction stage of the Lotus Temple [22]

The temple is predominantly built of concrete and clad in Greek marble, reflecting the pure white exterior of the Lotus Temple, whereas, the interior of the temple has been revealed in an expressionist style with an exposed precast ribbed roof . the white marble cladding used for the lotus temple is the same marble used by many ancient greek monuments such as the pantheon.it is from the Penteli mountain in Greece

By allowing the Cool air (heavy) drawn from the basement pools to enter and emitting the hot air (light) from the top, the central hall of the temple is designed to function as a chimney,thus creating a stack effect with openings at the top and bottom ensuring a continuous filtering of cool air through the pools in the basement and the hall. This process is reversed on humid days.

Fig 17. View of the pool [23]

The existing topography of the land was used to create large basements at the level of pools. The auditorium was lowered by five steps so that it can serve as louvers for cold air coming in. Two sets of exhaust fans support this process.

The first dome cools the concrete surface which stops the heat from being transmitted.The second dome cools the air from the hall to the basement which reuses it again.

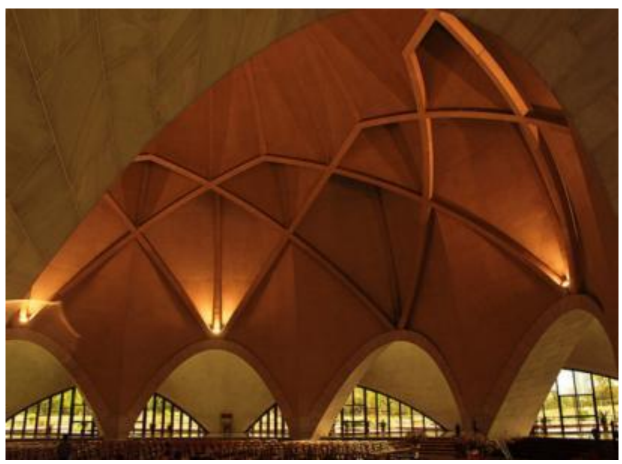

Fig 18. Interior view of the Lotus Temple [23]

The solar energy created by this building itself supply's some of the electricity for the temple, making the Lotus Temple the first to use solar energy resources in Delhi.

the architect designed the building to act as a skylight by mimicking the spherical form and the innermost patterns of the lotus flower .In the same way that light travels through the inside fold of the lotus petals, it reaches the hall as well.The central hall is supported by nine open "petals", each serving as a skylight.The central hall, thus, is like a bud composed of 27 petals, and light passes through these inner layers and is diffused in the space.

The entire building is designed in such a manner that the interior is well connected to the exterior. The entire structure, the podium and the pools have been built as an interconnected whole.[22]

10. Conclusion And Future Scope

The urban setting or the man-made structures are gradually being accountable for significant environmental problems all around with an increase in the generation of waste, excessive use of material and energy and the resulting GHG emissions. Important changes are increasingly required in order to help make sure the development, habitation, and protection of the built environment, in order to avoid more damage to the ecosystem and the climate. Long-term solutions are increasingly becoming necessary to bring the built environment in line with the effects of climate change. The imitation of lifeforms and the interaction among them that form the biosphere is not only a live example for humans to learn from but also an inspiration for them to design future buildings that can mutually and beneficially connect with ecosystems.

This research is an analysis of biomimicry and explores the creation of a design approach based on biological principles and materials. A real biomimetics strategy to the architecture involves the introduction of a new design approaches that include both designing and limiting materialization processes along with the environmental forces and its effects

The study explains how applying biomimetic principles and adaptable methods of natural organisms, processes and ecosystems can enhance the adaptive nature of building facades. Apart from the fact the principles overseeing the functioning of organisms can be used in architecture, for saving resources and energy, in finding more effective and environmentally friendly solutions, lowering costs and enhancing the quality and durability of construction, the adaptive characteristic of the organism can be used in designing facades, which can also be used as a tool for innovation in construction and design. In the absence of the principles behind these natural approaches, the mimicry of nature is limited only to a surface level, that can imitate the function of the organism but by sacrificing the advantage of the biomimetic method,

By studying the realistic methods of application, introducing the principles of biomimicry to architectural designs can become a possibility. Biomimicry can be assumed as a realization design tool for an architectural design solution. This can also be a phase of understanding of sustainable architecture. and so there are a large number of literary works done on biomimicry and its principles and its implementation in architecture It is important to analyze how these principles and ideas can be used in the design phase in the architectural field. The literature review showed the necessity to know the intentionality behind science and design. It also showed us how important it is to change our thought of trying to control, predict, exploit and manipulate nature. Literature analysis of biomimicry seeks to explain how to effectively and sustainably engage with nature. A biomimicry solution could be the most sustainable way to design a built environment that is reliable and useful. this study based on various literature works focuses mainly on biomimetic principles and materials and how it is possible to have a connection between biomimicry strategies architectural systems and the design process In most instances, it is found that the application of biomimicry to date is only being explored for object design. The outcome of the research is seen that of the three levels of biomimicry only the organism level has been applied in the design of the built environment. There is still a lot left to be explored in terms of biomimetic design in architecture. It might not be possible for us to alter people's actions but we can design structures that impact them. By doing this we are creating a built environment that enables people to reside and operate more productively thereby turning it into a unique and sustainable environment.

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