

BIOMIMICRY: AN APPROACH TO SUSTAINABLE ARCHITECTURE AND DESIGN

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Abstract: The purpose of this paper is to bring about the awareness of 'Biomimicry', a concept of adopting nature's principles and its application in the fields of architecture, engineering, and science to help create a more sustainable built environment for future generations. The study aims at using 'Biomimicry' as an approach for architects to integrate in their designs and understand the importance and need for doing so. This paper consists of a collective effort of various references from research papers that scholars have studied to highlight the current need for creating a sustainable built environment using the concept of 'Biomimicry'.

Design methodology – Through a comparative literature review, and an examination of existing sustainable practices, this paper elaborates on distinct approaches to biomimetic designs that have evolved and can be put to practice.

Findings – The paper has highlighted the various approaches of biomimicry that can be used in designs. Creating built structures through the inspiration of nature's principles can help eliminate several issues that are currently faced by humans and solve them through integration of 'Biomimicry' in design. Individuals' mind sets are shifting from a conventional thought process of building structures to a more eco-centric system which helps us utilize the available resources at its highest potential. Although it's a new concept introduced to individuals in the industry, it is quite likely to have a tremendous impact on the environment in the future, as a new way of bringing forward a sustainable solution that harmonizes with nature.

Keywords: Sustainable architecture, Green buildings, Biomimicry.

I. INTRODUCTION

The increase in globalisation in recent decades has brought about the need for thinking of more sustainable ways to create a built environment for man. Focusing on developing a sustainable environment for our future generations has come into light in recent times and architects are looking into nature for inspiration [1]. The new field of "Green buildings" or "Sustainable Buildings" has been gaining momentum in recent years due to the environmental impact of buildings[2]. In today's ecologically-conscious world, sustainable architecture has become one of the fastest growing architectural trends since the concept of "green buildings" emerged in the 1960s and 70s. The main aim of developing the concept of "green buildings" is to use only environmentally friendly methods and materials during the building process as well as reducing the negative impact of buildings through efficient energy consumption methods and space development [3]. At the rate of development in the world today and the constant use of the scarce and limited resources found on earth, the future of civilization has become quite uncertain. Unless there is a change in man's thinking and behaviour towards his day to day activities that have an effect on his lifestyle and, it is difficult to see further changes in the overall environment [2]. Sustainability is a goal for all to reach and the development of green buildings is one of the most efficient ways to accomplish this goal as it produces environmental, economic, and social benefits. The environmental benefits of green

buildings are reduction of pollution, conservation of natural resources, and prevention of environmental degradation. In an economic sense, it reduces the amount of money that is spent on water and energy and improves the productivity level of its users. Socially, green buildings create an aesthetic appeal to the local infrastructure [2].

The awareness and immediate need to act upon the matter of sustainable architecture and “green buildings” gave rise to a new concept known as “Biomimicry” [4]. Coined the term Biomimicry and defines it as a concept of adopting nature’s principles and applying it in engineering or science to help create a more sustainable built environment for future generations. In 1997 she wrote a book “Biomimicry: Innovation Inspired by Nature” and in 2006 she co-founded the Biomimicry Institute, a non-profit dedicated to making biology a natural part of the design process. In Biomimicry, she names an emerging discipline that emulates nature’s processes and designs, to create a healthier and a more sustainable planet. The release of her book has helped evolve the practice of Biomimicry in the 21st century and inspired a number of architects and designers to apply this concept into practical sense. The concept of biomimicry has been popularized not only because of its economic prospects, but also because of its tremendous capability to inspire eco-friendly designs at this critical juncture in human history.

Biomimicry creates a certain amount of curiosity through the design process as well as the final outcome of the project. For instance, Biological designs are volatile, multi-utilitarian, malleable, dignifying, and generally produce no waste at all. The in-depth knowledge of biology helps rethink the way of designing from a sociological model to a more product life cycle and earth system approach [5]. Although Biomimicry is a new concept introduced to individuals in the industry, it is quite likely to have a tremendous impact on the environment in the future, as a new way of bringing forward a sustainable solution that harmonizes with nature. Biologists are incorporating themselves with designers and architects to come up with projects to bring humanity closer to nature [6]. The main aim of implementing biomimicry into practice today is to get a number of people on board with the ideology and effectiveness of the concept to create a sustainable future for our society [7]. Biomimicry has been embraced by the green building sector as an interdisciplinary way to research on the design of buildings that are beyond the current meanings of sustainability towards restoration and regeneration. It has become an exceptional tool for creating more sustainable products and processes along with the benefit of adjusting to climatic changes as nature creates habitats where each organism is adapted to its location and conditions. Organisms constantly change their habitual behaviour in accordance with the change in conditions of the environment for survival purposes. Although there is a change in habitat conditions of species due to population growth, there has been no change in the strategies to tackle such situations [8].

Biomimicry has been a part of human history ever since the evolution of man, and several biomimetic designs have already been seen in today’s world. Some of the commonly seen biomimetic inventions include a.) The invention of the Velcro by Georges De Mestral. The inspiration was drawn from his dog running into a burdock bush and coming out with these burrs stuck to its fur, b.) Flying machines known as 'ornithopters' at the time, invented by Leonardo da Vinci who only drew the sketches of this idea but failed to put it to practice himself, c.) Buildings constructed based on the inspiration of Amazon River’s large water lilies [9]. Biomimicry is practiced based on the 26 principles out of which 6 of them have the utmost importance in shaping the design process of biomimetic structures [4]. These six principles known as ‘Life’s Principles’ were categorized and a detailed explanation for the same was given by the world’s leading consultancy firm in biological advancements. Today, similar practices along with latest advancements of technology have helped introduce further creative ways of implementing biomimetics into architecture and design [5].

Biomimicry is not only the concept of mimicking nature’s principles and putting them into practice, but with the main aim of solving human problems in the most eco-friendly and efficient way through the help of nature [10]. According to several authors, the relationship between Biomimicry and architecture is such that it focuses on three main approaches of reaching sustainability: form, process, and ecosystem. Each of which have a significant role through each stage of the application of Biomimicry in design which would be further discussed in detail through the various literatures of scholars [5]. Several scholars have given their thoughts on the benefits and criticisms on the concept of Biomimicry which is explained in detail in the comparative literature analysis.

The purpose of this study is to bring out the awareness of the concept of Biomimicry and its relationship with architecture along with sustainability. The objectives to be achieved through the comparative review of several research papers were: a.) to gain clarity and meaning on the concept of Biomimicry, b.) to understand the functioning and application process of Biomimicry into architecture and design, c.) the benefits and challenges that arise while practicing Biomimicry in the field

of architecture and design. Questions such as ‘What is Biomimicry?’, ‘How has nature been an inspiration in building the concept of Biomimicry?’ ‘How has it influenced architects in their design processes?’, ‘What are the benefits and challenges of implementing Biomimicry in a practical sense?’ have led to the need for studying this topic that have been addressed through the comparative study of previous papers.

A. Principles of Biomimicry

Biomimicry is based on an overall of 26 ‘Life’s Principles’ out of which 6 are of utmost importance to the designing of biomimetic structures [4]. These principles act as innovative tools through which biomimetic designs, matter, and procedures are assessed for sustainability [11]. These ‘Life’s Principles’, can be commonly found amongst all living species on the planet. These principles are characterized into 6 groups and further sub-divided into three to four principles each [12]. The 6 major principles stated by the Biomimicry Group are:

Resource Efficient

The ability to conserve and protect all of nature’s natural resources and use it at its optimum best by meeting several needs through one specific solution, minimising the consumption levels of energy, recycling the materials used for construction, and harmonising form with function in such a way that the structure is designed only on need basis[11].

Adapt to Changing Conditions

Nature is known to continuously adapt itself to the constant changing conditions of the environment. This principle talks about incorporating diversity of various forms, processes and systems to satisfy a basic need, maintaining integrity through self-renewal, and using alternative methods to achieve resilience [13].

Be Locally Attuned and Responsive

The effort of blending into and incorporating with the neighboring environment. This is done by using materials that are abundantly available in the vicinity, exploiting renewable energy at its best potential, creating a win-win situation through the cultivation of healthy relationships, trumping of nature’s practices that form a repetition, and the use of feedback to help better future practices [11].

Use Life-Friendly Chemistry

All life forms depend on scientific needs for their survival. Through the process of decomposing without harming the environment in any way, the arrangement of selective elements in an elegant manner, and using water as a universal solvent through the right channels to avoid any wastage [13].

Integrate Development with Growth

The process of endowing and involving in strategies that encourage not only growth, but development as well. This can be executed through moving from simple procedures to more complex ones, arranging components in a progressive manner, and creating conditions to allow elements to interact and move towards an upgraded system [12].

Evolve to Survive

The unremitting combination and analysis of information to ensure outstanding performance which include the repetition of existing strategies that have proved to be successful, inclusion of errors to help enhance future works and make progressive changes through time, and the trading and creation of new information to generate new ideas and processes [11].

These principles mould the framework of Biomimicry and allow practitioners to implement the concept of Biomimicry into their work in relation to the design inspired from nature [4].

Biomimetic Designs and Structures

Over the years, designers and architects have incorporated the concepts of Biomimicry into their designs. These innovations have led to the advancement and improved the quality of buildings and structures [7]. Some of the most creative designs based on Biomimicry are explained in the form of a table for better understating of the subject

Innovative Designs and Structures inspired by Biomimicry

Table 1: Examples of Biomimetic Designs and Structures

Structure	Description
<i>The Gherkin Tower inspired by the Venus Flower Basket Sponge.</i>	The Gherkin Tower in London was designed by the architect Norman Foster. The unique feature about this building is such that it mimics the design of the Venus Flower Basket Sponge, an organism found underwater which is structured in such a way that it is able to withstand the force of the currents. By using this as inspiration, Norman Foster.
<i>Daimler Chrysler's Prototype Bionic Car inspired by a Boxfish and Tree Structure</i>	Daimler Chrysler proposed a prototype bionic car based on the structure of a Boxfish (<i>ostracion meleagris</i>), a fish with an extremely streamlined body structure that enables it to resist any sort of turbulence in water and giving it a box like shape. In addition to the fish, he has taken inspiration from the growing dynamics of a tree and its stress reduction ability. The car is said to have a larger body with an extremely skeletal framework creating space for seating as well as improving fuel efficiency due to its frivolous design. It is also efficient in material utilisation, as only areas that require specific material, would it be added to [14].
<i>All Seasons Tent Tower Hotel inspired by the structure of a Volcano</i>	OFIS Architecture, a Slovenian based organisation proposed an All Seasons tent Tower in the city of Yeveran, Armenia. It was conceptualised in such a way that the two cylindrical structures mimic the pattern of a volcanic mountain which is covered with a green tent like layer. Since the city is a region of frequent earthquakes, the concept was built looking into the safety requirements during this period. The upright structure helps resist in gravity load as well as the magnitude of the earthquake [10].

Benefits of Biomimicry in Architecture

Through the understanding and interpretation of various authors and their views on the concept of Biomimicry, there are a numerous benefits that can be identified: a.) Customisation of buildings and structures based on environmental inspiration and the utilisation of available raw materials at its best potential [15] b.) Look at architecture as a sustainable [5] c.) Helps in making the structures more adaptable to changes in the environment [10] The most energy efficient and sustainable way to tackle human problems [6].

Scholars' Opinions on Biomimicry

Along with the benefits Biomimicry has on the environment, there are also a few criticisms on implementing this concept into practice: a.) The availability of resources being so limited causing a rise in the price of material as well as construction process of a building or structure [15] and b.) The lack of knowledge on the topic 'Biomimicry' making it a challenge for individuals to understand the functioning and application of this concept into architectural design [12].

II. RESEARCH DESIGN PROCESS, DISCUSSION AND INTERPRETATION

This study was carried out through the comparative review analysis of previously studied papers on Biomimicry and Architecture. A careful understanding of the evolution of architecture and Biomimicry were done before constructing the conceptual paper. Four key areas were selected and a detailed review under each of these categories were conducted to gain clarity on each of these topics. Through the in-depth research on these topics, the aim of the study was achieved and a clear understanding on the topics were gained as well. The studies conducted in each paper have had a significant impact on the understanding of the application process of Biomimicry in architecture and design.

The study defines the concept of Biomimicry and analyses its relation with architecture as well as green buildings by carrying out a comparative analysis of previously studied literatures on the topic. Biomimicry is comparatively a young concept that is being embraced in modern day architectural and design processes which aims at creating a sustainable environment for current and future generations tackling human problems. Although Biomimicry is being practiced in many countries around the world, people are still aloof of the concept and how it can be applied in various fields to achieve sustainable results. A possible explanation for this could be the relative late environmental awareness spread

across other nations. From the literature analysis of this study, it can be seen that several of the authors have spoken about the benefits, challenges, the relation Biomimicry has with architecture as well as the limitations of the concept.

An overview of the background of architecture, its history and the current scenario of architecture with the use of sustainability and green buildings is presented in this study along with their relationship with Biomimicry. Biomimicry incorporates the concept of sustainable development to integrate protection of the environment and human problems. Although, biomimicry has several benefits and contributions to the environment on a large scale, several authors gave their opinions of the research issues that they studied in their papers relating to Biomimicry and sustainable architecture. The study has also identified the principles based on which the concept of Biomimicry can be put to practice. These principles create a foundation for individuals to apply Biomimicry into their designs and incorporating various other principles that fall under the 6 categories. Using these principles as guidelines to implement Biomimicry, helps achieve the outcome in a much more efficient and effective manner. Examples of a few structures that have been inspired by Biomimicry has also been discussed in this study. A brief analysis on the key findings and research issues from the previously reviewed papers has been explained with the help of tables.

Table 2: Summary of Key Findings from reviewed papers.

Title	Key Findings
Architecture	The features of architecture and interior design are based on the attributes of human actions. Modern architecture is well defined and the design does not change from time to time. It can be recognized through its polished and modest interiors. Contemporary architecture focuses on constant change and the incorporation of creative ideas into the design process. The use of cement and steel frameworks developed during the period of modern architecture up until which focus was more on using brick walls to support ceilings and floors.
Sustainable Architecture	The buildings based on sustainable architecture have very limited negative impacts on the Environment. Sustainable architecture has helped architects and end users achieve the goal of reduced Waste generation during the process of building construction.
Green Building	Assessment tools are designed specifically for the assurance and reliability of the building being sustainable. Green buildings are highly region specific and depend on the materials and climatic conditions available in a particular region. Green buildings are high on initial investment but are immensely fruitful in the long run and provide several benefits. In order to ensure that a building is green or sustainable, specific materials such as wood, teak, glass, and anything that is renewable and can be recycled is necessary to use.

Research Issues related to Biomimicry and Architecture

Some research issues have been identified through the study on previous literatures which require attention from researchers and practitioners. These research issues may be classified into the following categories for better understanding of the subject: Category I: Buildings and Materials, Category II: Nomenclature and Meaning of Concepts, Category III: Knowledge and Clarity on the Concept or Topic

Table 3 attempts to highlight these issues with a brief attempt to explain these issues in detail.

Category	Research Issues
Buildings and Material	Focus is solely given on latest trends of architecture and not rooting back to ancient cultures. Issues on the designing process of public buildings were not discussed by the authors through the reviewed literature. Although the use of concrete and steel frameworks were spoken about, authors have not researched on RCC (Reinforced Cement Concrete) frameworks which were developed during the period of modern architecture.

Nomenclature and Meaning of Concepts	There is no specific definition of the term sustainability. Architects are unable to identify what factors to consider under the term 'sustainable'. Assessment tools are the only way to identify how 'green' a building is as there is no specific standard maintained for a green building to consider it as one.
Knowledge and Clarity on the Concept	Individuals are unaware of the concept of Biomimicry and its application to various fields such as Architecture, Engineering and Science. Sustainability as a concept in relation to architecture is required to be explained to a large number of people in order for individuals to consider living in and using sustainably built structures

The study has helped understand the meaning and concept of Biomimicry along with its application in various structures and buildings. The need for implementing this concept to provide future generations with a sustainable environment has been achieved through the review of previously studied literatures. The results of this study provide architects and designers with immense knowledge on a fairly new concept of designing and constructing buildings with the primary motive being sustainability in architecture and design. The study not only enlightens practitioners to put the concept into action but, academicians as well to incorporate 'Biomimicry' into their research and introduce it as a subject in institutes that offer architecture as a subject.

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