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Biomimicry as a Problem Solving Methodology in Interior Architecture

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Abstract

Biomimicry is an applied science that derives inspiration for solutions to human problems through the study of natural designs, processes and systems. The widespread and practical application of biomimicry as a design method remains unrealized; interior architecture commonly use biology as a library of shapes, but this alone is not biomimetics; it has to have some biology in it. This paper reviews key points and case studies of applications of biomimicry in interior architecture. A critique of the applications shows that biomimetics is the way to innovation and sustainability and interior architecture must move beyond the formalistic characteristics of nature.

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1. Introduction

Nature presents an endless source of inspiration for scientists and engineers from different fields of interest. Each organism is unique and is full adapted to its own environment. By responding to its need and finding solutions that work, nature evolves. This last through countless generations, while passing the test of survival to reach its next generation (Badarnah, 2009). The field of biomimicry, where flora, fauna or entire ecosystems are emulated as a basis for design, has attracted worldwide interest in the fields of

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architecture and engineering. This is due to both the fact that it is an inspirational source of possible new innovation and because of the potential it offers to create a more sustainable built environment.

The widespread and practical application of biomimicry as a design method remains however largely elusive. Although various forms of biomimicry or bio-inspired design are discussed by researchers and professionals in the field of sustainable architecture (Reed, 2006, Berkebile, 2007), the widespread and practical application of biomimicry as an architectural design method remains largely unrealised, as demonstrated by the small number of built case studies (Faludi, 2005).

The widespread and practical application of biomimicry as a design method remains, however, largely unrealized; interior architecture commonly use biology as a library of shapes or decoration (Art Nouveau, Jugendstil and the like), but imitating or being inspired by natural-looking forms, textures and colors alone is not biomimetics; it has to have some biology in it. This means that to be truly biomimetic, a design should in some way be informed by nature's science, not just its look. This paper reviews key points and case studies of applications of biomimicry in interior architecture that lay the foundation of this important movement. A framework to understand the different forms of biomimicry has been developed and is used to discuss each design.

2. Biomimicry overview

Biomimicry can be defined as imitating or taking inspiration from nature's forms and processes to solve problems for humans (Benyus, 1997). Janine Benyus, a biologist and leader of the emerging discipline of biomimicry provides one foundation for this emerging discipline by arguing for the need to imitate nature to ensure a more sustainable future (Benyus, 1997). Benyus and other leaders of biomimicry emphasize that, although the form is an obvious component of nature, mimicking natural form alone misses the point. Instead, Benyus argues that a full emulation of nature engages at least three levels of mimicry: form, process, and ecosystem (Benyus, 2008, p. 40).

Biomimicry is more than just reproducing a natural object or system. Nor is it simply designing something considered "green" or sustainable. It is first a close examination of an organism or ecosystem, then a mindful application of the underlying design principles found in the natural solution. Learning about nature is one thing and learning from nature is another. Nature has time-tested patterns and solutions all around us, and Biomimicry is the study and application of natural solutions to design challenges. "Nature is imaginative by necessity, and has already solved many of the problems we are grappling with today," says Janine Benyus (Benyus, 2008), founder and president of the biomimicry Institute. The world around us is a living encyclopaedia of ingenuity.

3. Biomimicry in interior architecture (technique not style)

When an interior designer says that a design is influenced by nature, he or she is most likely talking about its appearance: it has an organic shape. Nature is a good teacher in this regard, but imitating or being inspired by natural-looking forms, textures and colors alone is not biomimetics. To quote Dr Julian Vincent 'biomimetics has to have some biology in it.' By which he means that a design should in some way be informed by nature's science, not just its look to be truly biomimetic.

However, perhaps the key to understanding the role of biomimicry in interior architecture is the fact that the reason for the success of any design is not that it can trace its roots back to a natural principle but that it is an example of good design! Biomimicry is a philosophical approach that can lead to novel ideas and innovative solutions that have many potential advantages, for example, from functional or sustainability perspectives.

In interior design the fashion few years ago was for minimalism trend, this design language is hard-edged and machinelike but succeeds in being humane and friendly through its simplicity and careful use of materials. At present, the fashion is an organic encased in smoothly flowing forms and curvy details. For example, the curved spiral shell house which designed by Senosiain Arquitectos and was inspired by a sea shell. Inside the home, the odd forms of the exterior continue to wrap through and connect each space. The interior feels much as it could be outside, filled with plant life, organic patterns and winding stone paths, see Fig 1. The design depends on emulating the shapes and patterns and colors of the nature source, may be it has some sustainability since it able to withstand an earthquake and low- maintenance. But it does not a biomimic design at all.

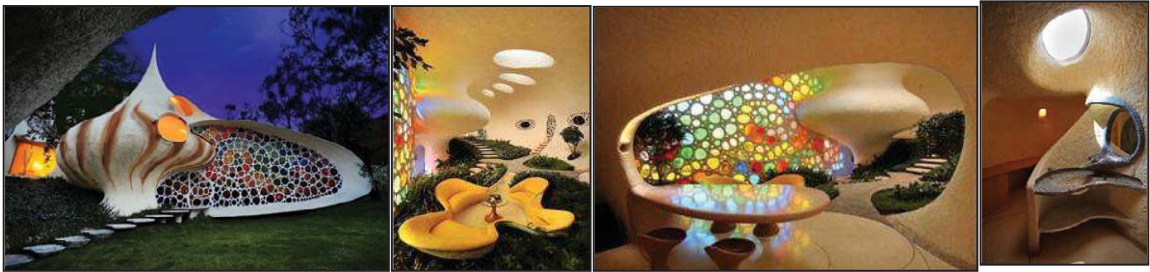


Fig.1. A spiral shell house, designed by Senosiain Arquitectos

In an attempt to link architecture with biology, Kulper (S.B. 2003) and Roy (S.B. 2005) designed the cell-shaped building for the Institute for Nanobiomedical Technology and Membrane Biology in Chengdu, China, the regional capital of Sichuan province in southwestern China. The designer intended to make the building look like a cell from the outside and to include an assortment of forms inspired by molecular biology inside, see Fig 2.



Fig. 2. Cell-shaped building for the Institute for Nanobiomedical Technology and Membrane Biology in, China.

According to Zhang, the pioneering design for the cell-shaped building was inspired by "elegantly folded protein structures and their simple and beautiful structural motifs. The cell-shaped building attempts to combine the architecture and the biology structures". Kulper said "the garden design inside the cell-shaped building includes such biologically inspired features as pools in the shape of endosmosis, left, and mitochondria", but this is not biomimicry this is emulating biological shapes and motives, the designer did not use the biology as a tool to solve problems or achieve function. The designer in biomimicry approach must ask "How would Nature do it?" biomimicry is more than just reproducing a natural object or system. It is first a deep study of an organism or ecosystem, then a mindful application

of the underlying design principles found in the solution of the nature, we can say that learning about nature is one thing- learning from nature is another.

This discussion of fashion and style is worthwhile because it is important to understand that biomimetics has nothing to do with appearance. A biomimetic design could easily be designed to look any organism shape, but it need not. So it is necessary for designers and architects to understand that biomimicry does not necessarily influence the appearance and style of a design. It could, but it does not have to, architects and designers should engage nature more deeply than merely mimicking natural form. They must move beyond the formalistic characteristics of nature and encourage people to develop a deeper and more responsive understanding of the nature.

4. A framework for understanding the application of biomimicry in interior architecture

A framework for understanding the different forms of biomimicry has been developed, and is used to discuss the application of biomimicry in interior architecture, see Fig 3. The framework redefines the different levels and approaches and also attempts to clarify the potential of biomimicry as a tool to solve problems in interior architecture. By defining the kinds of biomimicry that have evolved, this framework may allow designers and architects who want to use biomimicry as a methodology for improving the built environment to choose the best approach.

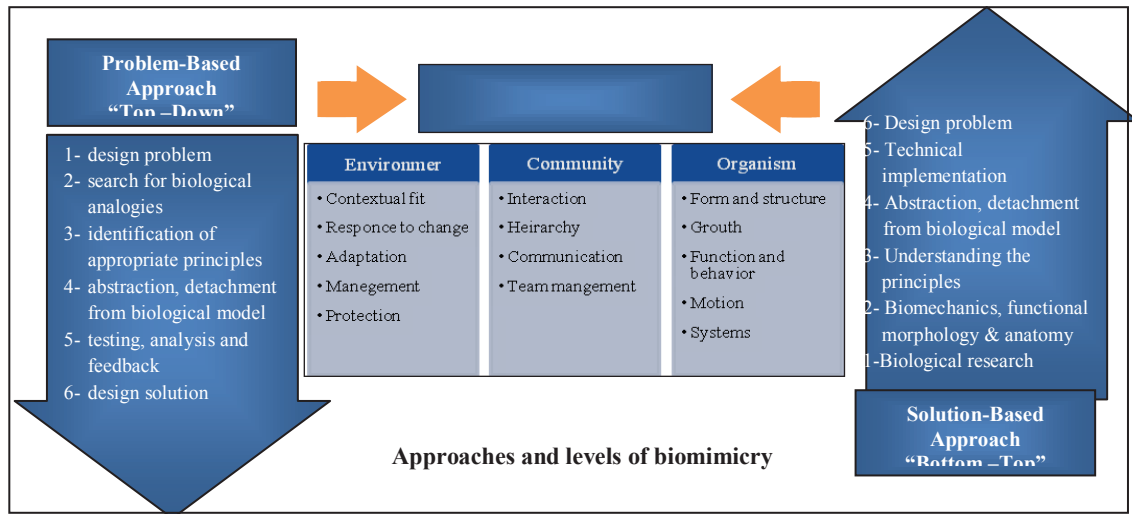


Fig.3. A framework for understanding the various forms of biomimicry

4.1. Design approaches

Approaches to biomimicry as a design process typically falls into two categories: Problem- based approach (Top –Down Approach) and Solution-based approach (Bottom-Top Approach).

4.1.1. Problem – based approach

This approach was found to have different naming “ Design looking to biology” (Perdersen Zari, M. 2007), “ Top Down Approach “ (Jean Knippers, 2009), Problem –Driven Biologically Inspired design (Michael Helms, Swaroop S. Vattam and Ashok K. Goel, 2009) all referring to the same meaning.

In this approach, designers look to the living world for solutions, requires designers to identify problems and biologists to then match these to organisms that have solved similar issues. This approach is effectively led by designers identifying initial goals and parameters for the design (Perdersen Zari, M. 2007). The pattern of problem- based approach follows a progression of steps which, in practice, is non-linear and dynamic in the sense that output from later stages frequently influences previous stages, providing iterative feedback and refinement loops, (Michael Helms Swaroop S. Vattam and Ashok K. Goel, 2009). Also, McDonough stated that this approach might be a way to begin transitions the built environment from an unsustainable to different to effective paradigm (McDonough 2002).

Research held in Georgia Institute of Technology by Michael Helms Swaroop S. Vattam and Ashok K. Goel, at the Design Intelligence Lab in 2006, also defined this approach through 6 definite steps are shown in Fig.4.

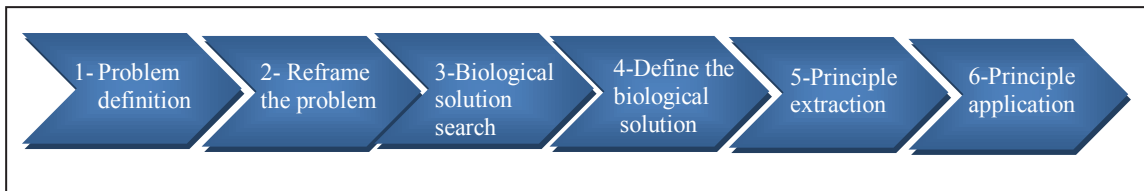


Fig.4. The steps of problem- based approach

4.1.2. *Solution- based approach*

When biological knowledge influences human design, the collaborative design process is dependent on people having knowledge of relevant biological or ecological research rather than on determined human design problems. An advantage of this approach is that biology may influence humans in ways that is at might be outside a predetermined design problem, resulting in previously unsought- of technologies system or even approaches to design solutions. The potential for true shift as in the way human design and what is focused on as a solution to a problem, exists with such an approach, (Vincent et. 2005). A disadvantage of this approach, from a design point of view, is that biological research must be conducted and then identified as relevant to a design context. Biologists and ecologists must therefore be able to know the potential of the research in the innovation of ingenious application.

Research held in Georgia Institute of Technology by Michael Helms Swaroop S.V. and Ashok K. Goel, at the Design Intelligence Lab in 2006, also defined this approach through 7 definite steps, see Fig. 5.

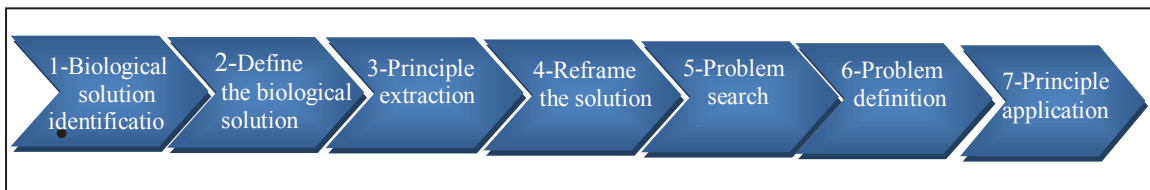


Fig .5. The steps of solution- based approach

In step 4, reframing forces designers to think in term of how we might see the usefulness of the nature function being achieved, and in step 6, whereas search in the nature domain contains search through some

finite space of documented nature solutions, problem search may contain defining entirely new problems. This is different from the solution search step in the problem- driven process.

Based on the above, the biomimetic solution has originated either from designers’ discussions with biologists, or biologists offering nature’s solutions to designers. Chance may appear to have played an important role in the process, and a first requirement for identifying the optimum solution to a designers challenge may appear to be in the development and adoption of a structured method of contact between the two communities.

4.2. Levels of Biomimetics Information

The information embedded in each organism can be found in many levels, which is summarized in Table 1, possible features that can be concluded from an organism and its biomimicry are analyzed using three levels. Each level is concerned with a layer of the design of an organism. The first includes aspects and properties of a creature as a whole unit. The second includes other features that focus on the relationships between an organism and its living community. The third level highlights systems and eco-solutions that can be concluded from relationships between an organism and its context/environment.

Table 1. Levels of biomimicry information

Levels of biomimicry	Aspects of the levels
Organism features (Features of the organism itself).	Formal attributes include shape, color, volumetric treatment, transparency, rhythm.
	Organization and hierarchy of parts and systems.
	Structure, stability and gravity resistance.
	Construction materials and process.
	Mutation, growth and lifecycle.
	Function and behaviour.
	Motion and aerodynamics.
	Morphology, anatomy, modularity and patterns.
	Portability and mobility.
	Self-assembly.
	Healing, recovery, survival and maintenance.
Homeostasis that balances internal systems while external forces change.	
Organism- community relationship (The organism’s relationships to its community of similar organisms as well as other creatures that it may deal with).	Systems which include organ, digestive, circulatory, respiratory, skeletal, muscular, nervous, excretory, sensory and locomotive systems.
	Survival techniques.
	Interaction with other creatures.
	Transgeneration knowledge transfer and training.
	Hierarchy of community members.
	Group management and coordination.
	Communication.
	Collaboration and teamwork.
	Self-protection.
	Sensing, responding and interaction.
Risk management.	
Organism-environment relationship (How an organism fits in its biome and environment).	The contextual fit.
	Adjustment to change.
	Response to climate by cooling, heating and ventilation solutions.
	Response to context by, for example, camouflage, self-protection and self-cleaning.
	Adaptation to ecosystems includes adjustment to various light or sound levels, shading, and self-illumination.
	Shelter building.
	Limited resource management such as adaptations to lack of water, light or food.
	Waste management.
Input/output/process cycling.	

5. Application of biomimicry in interior architecture

Five examples of applications and research projects were analyzed and served as case studies for the design approaches and levels discussed in the proposed framework, which is utilized here as analysis criteria for those examples, in attempting to investigate the potential of different design ideas.

Relying on the solution-based approach – organism features level - David Oakey and his team of designer working for Interface FLOR were asked to think about how nature would design flooring.” They came to realize that no two things are alike - no two sticks, no two stones, no two leaves. It is chaos, yet there's a pleasant orderliness in the chaos, said Interface Inc. Chairman Ray Anderson. Inspired by the organized chaos of a blanket of fallen leaves and a bed of river stones, the team discovered that none of nature's examples had exactly the same color makeup and contents, yet collectively they each created a complex and cohesive pattern. Oakey designers created Entropy, see Fig 6, which is inspired by the random patterns of the forest floor, achieving environmental advantages not found with other carpet tiles. Because the subtly-shaded carpet tiles blend together like leaves, without strict patterning, it is more easy to match the replacement tiles, less discards, more easy in installation, all ultimately resulting in the reduction of waste. In this way, biomimicry can benefit facilities managers and building owners.



Fig .6. Entropy floor mimics the random patterns of the forest floor

Smart paints, which use a self-cleaning technique borrowed from lotus leaves, also another example for solution-based approach where the Lotus leaf was the point of departure for the design. The information here was found in communication level that depends on the relationships between the organism and its living community. The paint surface takes the shape of densely packed ridges or bumps, just like the bumps found on lotus leaves. A property of such tiny bumps is that they prevent water drops from spreading out and the drops roll off the surface instead, taking the dirt with them, see Fig 7.



Fig.7. Self-cleaning principle borrowed from lotus leaves

This research project of Dr. A.J.N. Van Der Brugge with a group of scientists and biologists is an important example for the problem-based approach, as the designer asks a biologist to identify the animals and plants in which a certain function is available. The problem here was the desire to reduce glare and improve visual comfort in office buildings, without reducing view. This design is based on

strategies, principles, methods, and techniques abstracted from natural organisms that regulate light perception in their environment (organism-environment relationship level).

Several organisms were studied through a brainstorming session, and the fish was the selected organism based on its strategy in preventing glare by polarization of light, see Fig 8(a). Fish have a distinct alignment of its retinal cell to perceive polarized light. Light polarization is a technique used by the fish to reduce glare and improve its ability to create a good image of its prey or predator. Light polarization is an interesting phenomenon. If light is vibrating in one single direction and not continually changing of direction, the light is polarized. It is possible to filter light and make it polarized. The filter consists out of multiple thin stripes, which allow through only one single direction of light waves through and are able to reflect or absorb all other directions. Adding a second filter makes it is possible to change, or even fully block, the intensity of the polarization filter. This can be observed in the following pictures. (Goodwin, 2005)

Two design cases were been proposed and tested, one based on the technique of a polarization film and the other based on the principles of polarization by liquid crystals. Design case ‘Alpha’ is based on polarization by a polarization film. To be able to rotate the film, windows with circular shape were created; the rotation of the windows can be controlled manually or electronically. In design case ‘Beta’ polarization is obtained by LCs. LCs have the property to align easily and they are able to rotate using a voltage. There are four different phases, vertically polarized, horizontally polarized, non polarized and total light block. It is easy to switch between the different phases by a control panel. The switchable glazing could replace any standard window. The two cases will be able to fulfil multiple facade functions in just one simple glass layer, see Fig 8(b).

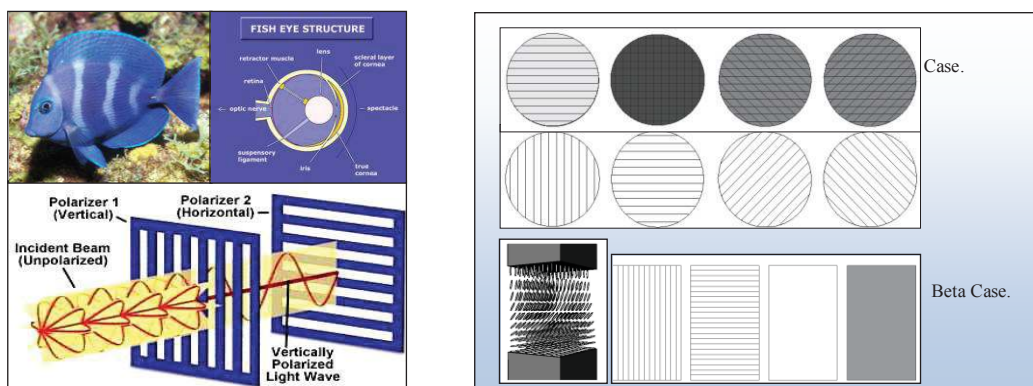


Fig.8. (a) The strategy of fish in preventing glare; (b) two design cases based on studying fish strategy

Based on solution-based approach Achim Menges in collaboration with Steffen Reichert in the institute for computational design at the faculty of architecture and urban planning at Stuttgart University studied the material systems in plants and they noticed that these systems are not only making use of an anisotropic material setup to adapt to structural forces. In combination with hygroscopic properties they can also perform kinematic and environmentally responsive movements without the use of muscles. In this case, unlike engineered solutions, simple material elements are sensor, actuator and regulator at the same time. These systems, therefore, provide unusual conceptual and practical framework for architectural surface structures that response to their environment. With the advancements in computational design, computer aided manufacturing and digital sensor technologies; an innovative materially-oriented design approach becomes possible, which enables the design and manufacturing of

surface structures response to climate without need for any mechanical or electronic control. According to the biomimetic research projects based on the biological principles of conifer cones, they presented some designs inspired by the method that cones protect the seeds inside; the spines close up to protect the seeds inside in the rainy weather and open up to improve the chances of the seeds escaping at the dry weather, see Fig 9. One of these designs is the FAZ Pavilion which located in the city centre of Frankfurt; the summer pavilion provides an interior extension of this popular public space. It responds to weather changes based on a relatively simple material element that is at the same time responsive structure, embedded sensor, no-energy motor and regulating element. The surface is fully opened on sunny days with relatively low ambient humidity. Once it begins to rain the related increase in relative ambient humidity triggers a rapid, autonomous response and the structure closes and forms a weatherproof skin.

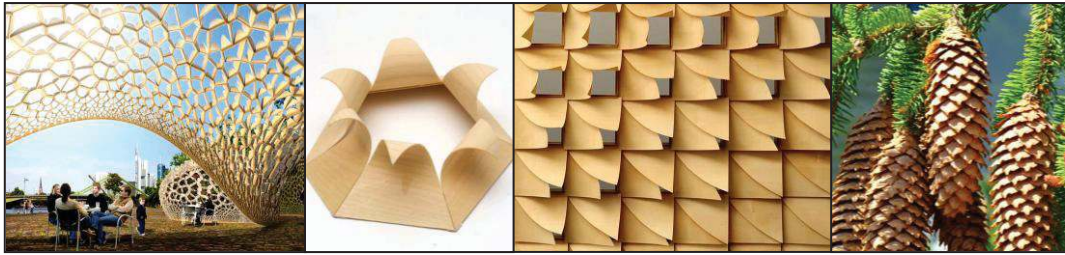


Fig.9. Research projects based on the biological principles of conifer cones

The case studies emphasize that integrating biomimicry within interior environments requires introducing the approach at the early stages of the design process, ideally before any preliminary ideas have been formed. It also involves inviting a biologist to the design table as a full team member, not as an add-on specialty consultant or afterthought. All the case studies address environmental issues at the habitat scale, and gives significant sustainable outcomes. In fact, studying nature will help us discover sustainable and effective solutions to the most important issues in the interior environments, day lighting, thermal comfort, energy efficiency, durability, and productivity.

6. The future of biomimicry in the interior environment

Now, biomimicry is still in its infancy in the interior environment. In spite of a growing number of bio-inspired materials and products are expanding the friendly environment options available to designers; projects that incorporate biomimicry at the macro scale are few and far between. It is expected that it will continue to be applied most widely in architecture and interior environment in the future, particularly as a tool of sustainable design in terms of day lighting, energy consumption and ecological footprint of new facilities. The architectural and interior design profession are cohesive enough to allow innovative approaches and new technologies to spread rapidly particularly when the profit is clear.

As an example, the ability to effectively provide daylight into an interior space that has limited access to it reduces the need for artificial lighting. As a result, less heat is generated and less cooling is necessary, which could reduce cooling equipment's size (a capital cost). Overall energy use is reduced (a cost of operation), and the dependence on fossil energy is lessened (an environmental cost). This is in addition to the important aesthetic and human benefits that daylight offers.

We can say that using biomimicry as problem solving methodology can help create a new sustainable standard for interior spaces, buildings, communities and cities worldwide. For architects and other design professionals, it opens up a whole new world of innovative ideas for transforming the interior

environment, while optimizing human well-being. And beyond the projects themselves, the principles of biomimicry will help in providing design smarter, and connect the work with the natural environment.

In the future, the interior spaces we live in and the workplace we work in might be designed to function like living organisms, specifically adapted to place and able to provide all of their needs for energy and water from the surrounding nature. The architecture and design will have inspiration, not from the machines of the 21st-century, but from the butterfly that flies in the sky or the flower that exists in the landscape that surrounds them.

7. Conclusion

The paper considers two designs inspired by nature. A critique of these designs identifies that biomimetics has nothing to do with appearance. A biomimetic design could easily be designed to look any organism shape, but it need not. The designers must move beyond the formalistic characteristics of the nature and encourage people to develop a deeper, more responsive understanding of the nature. The paper also reviews key points and case studies of applications of biomimicry in interior architecture that lay the foundation of this important movement. A framework for understanding the different forms of biomimicry has been developed and is used to discuss each design methodology. The case studies emphasize that integrating biomimicry within interior environments requires introducing the approach at the primary stages of the design process, ideally before any preliminary ideas have even been formed. It also involves inviting a biologist to the design table as a full team member. The paper also identifies that using biomimicry as a problem solving methodology will help us discover sustainable and effective solutions to the most important issues in the interior environments: day lighting, thermal comfort, energy efficiency, durability, and productivity.

To the expansion of biomimetics, education must play a significant role. It should be included in the education syllabus of architecture and design degrees to make them aware of the potential of the approach. Also, networks, workshops and events could help forge links and transfer knowledge between the designers and the biologists.

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