Critical Essay

The Relationship Between Biomimetics and Design

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Abstract

In all sciences, nature is used as a guiding spirit. A domain exists which makes progress through the imitation and observation of nature. This domain, which is called biomimetics, can be expressed as the learning the rules of the life system in nature. As in many areas, in the field of architectural design behaviour is seen to imitate nature. The aim of this paper is to understand that relationship and where its successes and limitations lie.
The purpose of this paper is two fold: (a) to reflect on the relationship between biomimetics and architecture (b) to reflect on the interface between technology and biomimetics.
This paper contains two case studies. (1) to define and understand biomimetics in architecture. (2) to define and understand biomimicry in architecture.
Our conclusion points to the fact that nature has evolved successful systems, over many years of successes and failures, through natural selection that can be mimicked to solve design problems with the use of technological advancements.

Introduction

Biomimetics is quickly emerging as one of architectures' primary tools for the future. From bricks grown from bacteria to cement derived from the coral reefs building process, architecture is moving towards biomimicry with vehemence. When nature faces a problem, evolution weeds out inefficiency and what doesn't work and automatically selects the most effective adaptations. Humans also, solve environmental problems using biomimicry, for example, by examining nature's solutions and then applying them to human designs. Early examples of biomimetics are found in Leonardo da Vinci's sketches for flying machines and in the work of Filippo Brunelleschi: after studying the strength of eggshells, the Renaissance architect designed a thinner, lighter dome for his cathedral in Florence, completed in 1436. Later, in 1719, paper producers shifted from using cotton and linen fibres after French entomologist Réne-Antoine Réaumur suggested the wasp's use of wood pulp in nest-building demonstrated a better alternative. In 1809, naval architect Sir George Cayley studied dolphins to make ships' hulls more streamlined. Yet perhaps the most famous example of biomimicry came in 1948 when Swiss engineer George de Mestral walked his dog: it emerged from the bushes covered in burrs. After examining the burrs' tiny hooks under a magnifying glass, he designed Velcro.

Biomimetic innovation has flourished over the past 20 years: we have satellite parts inspired by the folding patterns of hornbeam leaves, a lightweight concept car based on the boxfish, and a medical probe inspired by the way the wood wasp "drills" into wood with minimal force and without a rotating drill bit. Today, biomimetics could be applied in architecture to address climate change, food, energy and water security; to cope with resource shortages or biodiversity loss; and in building sustainable cities.

The discipline of biomimetics is firmly established within the realm of design sciences, therefore, the term is clearly definable. From the beginning of 1970 biomimetic work was defined as follows: "learning from nature for self sufficient, engineerable design." Nature provides inspiration that one cannot blindly copy. It has to be incorporated into the very heart of structural design & weaved into the art of his or her science. One should remember that "nature provides no blueprint for technology." Therefore, reemphasising underlying the viewpoint that the general stimuli from the most diverse sources can have influences on design. Direct copies can never sustain or achieve the ultimate goal.

Biomimicry draws inspiration from varied aspects of nature and therefore lends itself to be used in different systems depending on its complexity level. It can work on three levels: the organism, its behaviours, and the ecosystem. At the organism level, architecture looks to the organism itself, applying its form and/or functions to a building. For example, Foster's Gherkin's hexagonal facade was inspired by the Venus Flower Basket Sponge. This special sponge hosts a lattice like exoskeleton that appears glassy and glowing in its underwater environment. The various levels of fibrous lattice work help to disperse stresses on the organism in various directions and its round shape reduce forces due to strong water currents. Both of these concepts were applied to Foster's design of the tower. At the behaviour level, the building mimics how the organism interacts with its environment in order to build a structure that can also fit in without resistance to its surrounding environment. The Qatar Cacti Building designed by Aesthetics Architects is one that uses the cactus's relationship to its environment as a model, for building in the desert. The functional processes silently at work are, inspired by the way cacti sustain themselves in a dry, scorching climate. Sun shades on the windows open and close in response to heat, just as the cactus undergoes transpiration at night rather than during the day to retain water. This project also reaches out to the ecosystem level. In its adjoining botanical dome, it follows processes that conserve water and has minimum waste outputs for its wastewater management system. The dome will create a climate and air controlled space that can be used for the cultivation of a food source for employees. Building at the ecosystem level mimics how diverse components work in tandem in different environment. These tend to be urban scale projects or large projects with multiple elements rather than a simplistic solitary structure. The Sahara Forest Project designed by the firm Exploration Architecture is a greenhouse that aims to rely on solar energy alone to operate a zero waste system. This project is at the ecosystem level because it has different components working together in a cyclical system.

In my view, although the terms biomimetics and biomimicry are used as synonyms for each other, have a distinct difference between them. The term biomimetics derived from 'bio' meaning life and 'mimetic' meaning 'relating to' is a philosophy of architecture that seeks solutions in nature, not by replicating their forms, but by grasping the rules that govern these forms. It is a form that follows a set of principles rather than specific stylistic codes. Whereas, 'biomimicry', derived from 'bio' meaning life and 'mimicry' meaning imitation, is the imitation of models and systems in nature to solve complex human problems. In my view, biomimetics is the process that should be taken into account when using it in architecture and not simply mimicking the existing forms within nature. The concept of biomimicry is a simple copy paste system from nature to complex structural system. It, just, takes models and systems from nature and directly plugs it into architecture. There is no adaptation or room for improvement and growth. Whereas following a biomimetic process, represents an evolutionary process and natural progression.

Case Studies

Two case studies have been analysed to understand the inherent difference between biomimetics and biomimicry.

Silk Pavillion_MIT Lab
Biomimetics

Inspired by the way silkworms weave delicate cocoons from a single strand of silk, the pavilion was created, using a base of robot-woven threads wrapping a steel frame. This was completed by six thousand five hundred live silkworms which were let loose upon this primary structure. Through a combination of careful design of the primary structure and the silkworms' instinctive preference for darker areas of the pavilion's surface, the pavilion's mottled skin finds the mid-point between a scaled-up version of the insects' own cocoons and a functional space for humans. Painstaking research was made into the way silkworms interact with their environment; from testing out different 3D spaces under different ambient conditions to using minuscule motion tracking equipment to examine the cocoon construction process. These findings, then, informed the construction of pavilion itself - determining both the path of the CNC machine which wove the panels and the density of the thread, which then served as the foundation for the silkworms themselves. The overall aperture and density distribution was first tracked with the use of specific software's solar mapping for heat and light and locking apertures were defined. From this, the general aperture generation logic was derived and the silk work spinning average was calculated. Thereafter, the structure was fabricated.

The most fascinating aspect of the Silk Pavilion is the way it connects the dots between the world of information technology and biology. Research shows how the blind instinct of silkworms is sometimes revealed as almost machine-like, "parallel basic research explored the use of silkworms as entities that can "compute" material organization based on external performance criteria". This was then mirrored in the use of a CNC machine to construct the 27 panels which make up the primary structure of the pavilion.

By analysing the silk worm, and thereafter, deriving the system logic of the silk worms weaving method using various computational tools, the structure was created. Thus, the silk pavilion is an example of biomimetics in architecture because the rules of nature were first grasped and then put into practice to create the pavilion.

Lotus Temple_ Fariborz Sahba
Biomimicry

Popularly known as the Lotus Temple, the Bahá'í House of Worship in New Delhi, India is a house of worship that was designed by Iranian architect Fariborz Sahba and completed in 1986. In keeping with Bahá'í scripture, the Lotus temple is organized as a nine-sided circular structure. It comprises of twenty-seven “leaves”, marble-clad free-standing concrete slabs, organized in groups of three on each of the temple’s nine sides. The structure is inspired by the lotus flower and is arguably one of the most visible instances of biomimicry in contemporary architecture. The aforementioned “leaves” are integral to the organization of the space and are classified into three categories: entrance leaves, outer leaves, and inner leaves. The entrance leaves (nine in total), demarcate the entrance on each of the nine sides of the complex. The outer leaves serve as the roof to the ancillary spaces, complemented by the inners leaves which form the main worship space. These inner leaves approach, but do not meet at the tip of the worship space and are capped with a dramatic glass and steel skylight. It is, therefore, observed that in this example the literal forms of the lotus flower have been directly transferred into the Bahá'í temple structure.

Through these two case studies, it is evident that the philosophy that architects and designers should be following is biomimetics. While biomimicry has its valid purposes, it is successful at the organism level, however, when that is converted into design it means that it is successful in an isolated level which is then stagnant. This is because it is simply the copying of models in nature that are already existing. There is no real room for improvement or innovation to the success of the design. However, with the idea of biomimetics; because it is an evolutionary approach to design there is a great opportunity and room for advancements. Because it is an additive system; where a set of principles are derived from nature, researched using various physical experiments and advanced computational tools, there is a progression of moving forward to tackle more complex problems. It is only through this evolutionary process will design create solutions that are optimum to the current existing culture, ecology and context. Hence, in my view, it is biomimetics that holds a higher value in the field of architecture or design and has the greater potential for advancements in design science.

Biomimetics Limitations

In fields from robotics to materials science, humans are increasingly borrowing ideas from nature, and with good reason. Nature's designs have, by definition, stood the test of time, so it would be foolish to ignore them. Evolution is intrinsic and the lifeline of Nature. Although, the technology that has evolved in nature is not always ahead of man-made technology, it is safe to assume that organisms have ways of implementing functions more efficiently and effectively than humans, in many cases.

In my view, the main criticism with biomimetics is the presumption that, after all the years of evolution and experimentation with technology and man made solutions, biomimicry risks presuming the superiority of nature given solutions over that of manmade ones. In idolizing nature’s systems and devaluing human design, biomimetic structures cannot keep up with man-made environment and its problems. Evolution within humanity, is culturally based in technological innovations rather than ecological evolution. To be relevant, a more practical approach should be taken towards biomimicry. Biomimicry presumes that by blindly emulating, copying and plugging in what exists in nature into our highly complex problems it is the safest solution. Safest, because it has stood the test of time as is evident from Nature's existence. However, we assume far too great a risk of completely getting our ideas from nature and not following through with man made advancements.

The problem is that the engineers looking for solutions depend on biologists having already found them—and the two groups move in different circles and speak very different languages.A natural mechanism or biological property must first be discovered by biologists, described in technological terms, and then picked up by an engineer who needs to identify and recognise its potential. To be effective, biomimetics should be providing examples of suitable technologies from biology which, in turn, fulfil the requirements of a particular engineering problem.

However, architects and engineers do not base their designs strictly on nature but, only use parts of it as inspiration for architectural solutions. Since the final product is actually an amalgamation of natural design with human innovation, biomimicry can actually be understood as bringing man and nature in harmony with one another. With the insertion of technical know-how and our current technological analysis tools, the natural structures derived through biomimetics can be made superior & relevant, than if it is understood from the biological standpoint alone.

Interface between biomimetics and technology

At the moment with the development of artificial intelligence in the 21st century, technology is at the heart of architecture's future. This leads to the question 'what is the relationship between the age-old systems of nature with the cutting edge technology of the 2st century? Are they two completely separate streams? Are there confluences? Or, is technology in a manner part of nature itself? In the end, all research and evolution is a part of a large continuum even if they are at different corners and in the beginning, seem to be using different tools. It is natural evolution itself that has led to fascinating systems, structures and processes. Ultimately, evolution is also the source for human being's intellect and only from that has the idea of human technology been born. Thus, technology is nothing more than the continuing of natural evolution. Therefore, nature and technology form parts of a continuum. The most important tool to understand this integration of both nature and technology is biomimetics.
Perhaps the process of evolution can be used directly in a biomimetic approach. By using high-speed computers, an initial design can be subjected to various combinations of selection pressures. As the design "evolves", each configuration could be tested virtually to assess its level of performance. Like evolution, this would be an open-ended process and new selection pressures could be introduced to produce alternative branching pathways. Designs considered as useful could be manufactured without a haphazard development phase and without a prolonged time of testing prototypes. Collaborations become essential and the union between biologists and designers is critical to biomimetics.

Conclusion

After billions of years of evolution, nature developed materials, algorithms, structures and mechanisms that work, which are appropriate for the intended tasks and which endure. The evolution of nature led to the introduction of highly effective and power efficient biological mechanisms. Failed solutions often led to the extinction of a specific species. In its evolution, nature archived its solutions in the genes of creatures that make up the life around us. Imitating nature's mechanisms offers enormous potential for the improvement of our life and the tools we use.

Humans have always made efforts to imitate nature, and we are increasingly reaching levels of advancement where it becomes significantly easier to mimic biological methods, processes and systems. As architects and engineers move from the world of large, stiff, right-angled pieces of metal to one of small, compliant, curved-surface pieces of heterogeneous parts, nature will become a more influential teacher. Perhaps the process of evolution can be used directly in a biomimetic approach. By using high-speed computers, an initial design can be subjected to various combinations of selection pressures. As the design “evolves”, each configuration could be tested virtually to assess its level of performance. Like evolution, this would be an open-ended process and new selection pressures could be introduced to produce alternative branching pathways. Designs considered useful could be manufactured without a haphazard development phase and without a prolonged time of testing prototypes. Collaborations become essential and the union between biologists and designers is critical to biomimetics.

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