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BIOINSPIRATION FOR ARCHITECTURE

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ABSTRACT
Biological evolutions have been taking place for millions of years and the species have made refinements to evolve survival strategies suitable to different climatic and environmental conditions. These evolutions have been inspiring the generations of scientist in areas of their research interest. The good aspect of biological species is that they live in harmony of other species and instead of harming the other they support the species nearby. The species in nature have a very neat and clean system of mutual co-existence. This is in total contravention of the developments done by the human being. The present paper tries to explore the biological species to get inspirations for the design of buildings in a way that the buildings start functioning as the bio-species do. It is said that everyone has something inspiring from biological species. As an architect planner the authors have tried to collect inspirations from biological species with an idea of making buildings that are less polluting, less energy consuming and are comfortable to live-in even in the changing climatic conditions. The authors are of firm belief that the valuable lessons derived from nature shall certainly help architects in producing better and sustainable architecture.

1. INTRODUCTION

1.0 Nature: A Source of Inspirations

It is worth pondering on as to where does ideas originate for any kind of activity or the research or invention. On a close introspection it shall be evident that the Mother Nature has been providing the source of inspiration to all, be it the scientist, artists, engineers, architects, poets or a person in any other vocation. Of the great scientists, Kepler and Newton developed the first empirical descriptions of gravity by studying the motions of the Sun and the planets. Faraday and Maxwell derived the fundamentals of electromagnetism by examining interactions between electrical currents and magnets. Thermodynamics was derived from studies of heat transfer and mechanical work. Quantum mechanics originated, in part, from spectroscopic studies of light. (Whitesides, 2015)

The architects and engineers have been getting inspirations from the nature for

development of the forms, shapes and even the structural systems. This is due to very long association of the human being with the nature. This close proximity helped the individuals to examine different aspects of nature very closely and adopt the inspirations in the practice. There could be different aspects of nature that provide inspirations to the researcher or the individual working on a particular aspect. It could be single cell, the plant life, the birds, animals and insects and their behaviour and development. All such and many more aspects may be inspiring in isolation or collectively to an individual who has been closely vouching it. Here the authors have discussed the bio-inspirations and how they have changed the world and how the same study could be adopted in development of a more humane and nature friendly architecture.

2.0 BIO-INSPIRATIONS

According to Cambridge Dictionary 'Bioinspiration is the synthesis of novel materials, devices and structures inspired by biological evolution and refinement which has occurred over millions of years. Bioinspiration aims to replicate key design principles and features in order to enhance the synthetic design. Bioinspiration differs from Bio-mimicry in that the latter aims to precisely replicate the design of biological materials.' It is really very clear that one tries to take inspirations from the Biological components. On is not trying to imitate the material.

Bio-inspirations are the only 'inspirations' from biology and obviously shall be of the useful aspects. Biology is the study of life and could be from single cells to complex organisms as such one can be inspired by any one of them. Today Biology has led to a rich mixture of other aspects that may not exclusively be focused on living systems, and one of these offshoots is 'bio-mimicry' or 'bio-imitation'(Baumeister, Tocke, Dwyer, Ritter, & Benyus, 2012). The objective of Bioinspiration is to mimic or imitate 'characteristics' of biological systems in non-living systems, rather than replicating or analyzing the biological entity itself. As an example, the processes—the combination of systems of sensors, muscles and brain (and other organs that process information)—that allow a squid to control its tentacles are still beyond us. Understanding enough of the mechanics of a tentacle to mimic some of its characteristics, even if the mechanisms used in that mimicry are unrelated to those used by the squid, is a simpler, more immediate, and perhaps more useful activity. Understanding the squid (or any living creature) in molecular-level detail is a subject of such multilayered difficulty that it will probably occupy much of science for the next century. Abstracting simplified versions of squid-like behavior—that is, taking inspiration from its capabilities, and mimicking some of its functionality, but using simplified and probably different mechanisms—is a related, but distinct Endeavour with enormous appeal, and with the potential both to stimulate the invention of new processes (i.e. processes found neither in squid nor, at present, in synthetic systems), and to use these processes to solve problems that a purely biological solution would not be able to solve' (Whitesides, 2015)

The initial human habitations were in close synergy with the nature. They were made out of the natural produce and in the nature. It is the process of urbanization triggered by industrialization that the man-nature distance started increasing. Today in the process of environmental crisis, it is felt necessary to go back to the basics and have a close look at the nature once again, this time with fresh perspective to derive fresh inspirations and have a second thought to utilise these inspirations in our building industry, in synergy with the modern technology, to make it compatible with the processes of nature and relevant to modern times.

3.0 INSPIRING EXAMPLES FROM NATURE

Nature is full of very inspiring examples that have been used and could be useful for the human beings. One only needs an inquisitive eye and keen interest in finding a suitable solution. A close and investigative look shall reveal that the nature is full of surprises for everyone. An accidental finding by a biologist may certainly be useful by an engineer or a material scientist looking for material suitable for the spaceship or the one trying to evolve self-cleaning surfaces for tall buildings. In its 3.8 billion years of evolution history nature has developed many aspects related to human being that we are trying to solve today. The authors have tried to list some of the inspiring examples that have already been found and used or could be used in the times to come:

3.1 Spider Silk

Spider silk which looks so fragile, but it is 5 times stronger than Steel.

According to Courtney Miceli posted in AAAS on Nov. 20, 2018 'To find out how most spider silk is five times stronger than steel, scientists analyzed the silk that venomous brown recluse spiders use to create their ground webs and hold their eggs, using an atomic force microscope. They found that each strand—which is 1000 times thinner than a human hair—is actually made up of thousands of nano strands, only 20 millionths of a millimeter in diameter. Just like a tiny cable, each silk fiber is entirely composed of parallel nano-strands, which they measured to be at least 1 micron long. That may not sound very lengthy, but on a nanoscale, it's at least 50 times as long as these fibers are wide—and researchers believe they could stretch even further.'(Miceli, 2018) Though the synthetic spider silk may be extremely difficulty to produce, such studies could pave the way for creating new materials that could be used in medicine and engineering.

A spider alone can inspire innumerable research programs. A person from robotics can learn from its gait. Materials scientists may aim to recreate the strength of its silk and its structure. And one can also study its vision characteristics. All these features can be useful to an architect if he tries to adopt the characteristics in his designs.

3.2 The Boxfish (Ostracion cubicus)

The Box fish is the fish that is found in the salt waters and has inspired designers of Bionic car by Daimler Chrysler (Mercedes Benz) 2007. It was assumed that due to the extreme agility with which boxfish maneuver, that their shape was aerodynamic and self-stabilizing. The car consumes 20% less fuel and produces 80% less nitrogen oxide. (Singh, Kumar, Joshi, Shukla, & Kumar, 2019) (Sudhakaran, Singh, Kumar Assistant Professor, & Joshi Assistant Professor, 2017)

3.3 Gecko foot hair

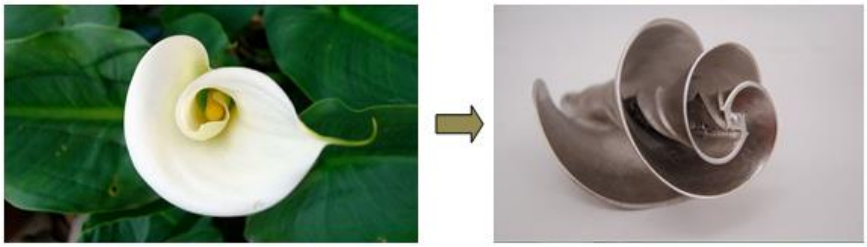
The study of Gecko and its foot hairs mechanics has inspired production of the re-usable super adhesive patented as Geckskin™. (Singh et al., 2019)

3.4 Rose Thorns

The commonly used wire for fencing and protection of the properties has been inspired by the thorn of the rose plant and it was patented way back in 1868 by Michel Kelly Patent. (Biomimicry 3.8, 2017)

3.5 Calla Lily

The shape of Calla Lily inspired tha Pax Technologies for development of a liquid mixer. The flower's centripetal spirals assist with the ideal flow of liquid, which allows their design to mix more liquid with much less of the energy usually required. Using nature's perfected designs helps minimize energy requirements.



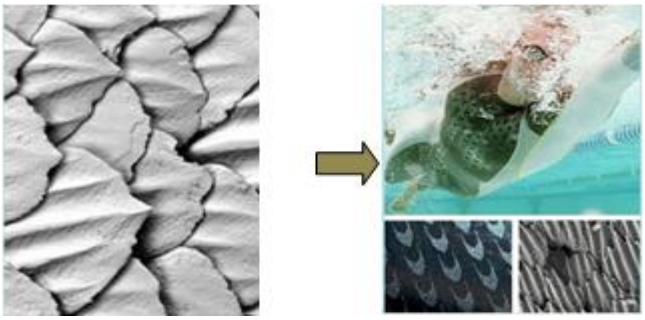
3.6 Butterfly

The structural system of the feather of commonly available butterfly has inspired the designers in development of a lightweight chair.

3.7 Shark skin

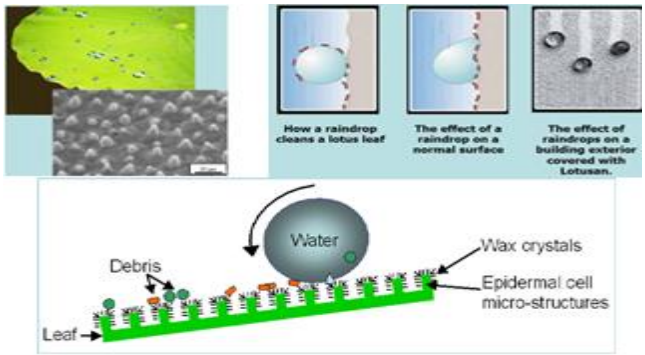
Sharks are known as the fastest and most agile swimmer. Its skin inspired the development of fabric to produce swimsuits. The U-shaped channels on a Shark

generate tiny vortexes that bring water closer to the body reducing the drag. This development led to production of a new type of swimwear liked by many winning swimmers of the world. (Singh et al., 2019)



3.8 Lotus Effect

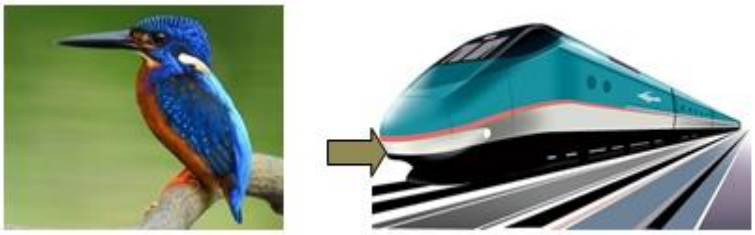
Lotus effect is the self-cleaning property of the Lotus leaf. Lotus flower emerges clean from swampy waters. 'Lotusan' paint has adopted these properties and it enables buildings to be self-cleaning. Nature can influence humans in ways outside predetermined design problem. We need to look at it with fresh eyes and open mind to find solutions/ applications in the ways that were not tried earlier and find fresh and innovative design solutions. (Benyus, 2002)



Water forms droplets on the tips of the epidermal protrusions of the Lotus leaf and collect dirt and pollutants as it rolls down the leaf. Same quality has been adopted in the Lotusan Paint

3.9 King Fisher

King Fisher is the source of inspiration for the Bullet Train. The designers studied the behavior of the King Fisher and realized that it is the shape of his head and beak that helps the bird to fly fast and drop into water with least of splash. Adoption of beak like shape for the front of the bullet train helped engineers in drastically reducing the boom that earlier versions were creating due to high speed and helped in saving of 10% of energy due to the aerodynamic effect.



3.10 Mussel

Mussel is the common name used for members of several families of bivalve mollusks, from saltwater and freshwater habitats. These groups have in common a shell. They also release a very sticky substance that keeps them stuck to the surface that they move. The Columbia Forest Products looked at the natural adhesive abilities of the blue mussel and came up with a way to use soy-based formaldehyde-free technology in the construction of hardwood plywood products


3.11 Sunflower

Researchers from Massachusetts Institute of Technology and RWTH Aachen University have studied the geometrical array of sunflower florets and used the information they gained to improve the efficiency of a concentrated solar power (CSP) plant, PS 20 over PS10, in Andalusia, Spain.


3.12 Star Fish

A starfish may not use its appendages to grip objects, but its form inspires mechanical structures that do. The Pneumatically actuated soft robotic grippers, which resemble the shape of a starfish, can gently pick up and release an uncooked egg and other fragile, irregularly shaped objects with ease.

4.0 ARCHITECTURE INSPIRED BY NATURE

Architects in past have been inspired by nature for shape of the buildings, structural system etc. Following are some of the architectural examples that have been inspired by the Nature:

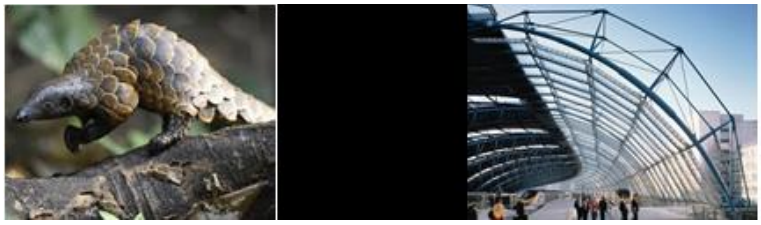
4.1 Eiffel Tower

The Eiffel tower has it inspiration from the thigh bone or the Femur bone, and has been constructed in- Exposed iron. IT need be noted that the outward flares at base

resembles the upper curved portion of femur. The internal wrought iron braces closely follow design of original trabeculae within femur. Due to its design the tower can withstand bending and shearing effects due to wind.

4.2 Waterloo International Terminal:

Source of inspiration of the Terminal building is Pangolin. Steel & glass has been used for construction. The glass panel fixing that makes up the structure mimic the flexible scale arrangement of Pangolin and has achieved extra **a**bility to move in response to the imposed air pressure forces when trains enter and depart.



4.3 Eastgate Centre Harare:

Eastgate Centre Harare building is designed with a unique ventilation system inspired by termite mound and draws outside air and cools or warms the interiors depending on temperature. The temperature remains regulated all year round without using conventional air-conditioning or heating system.

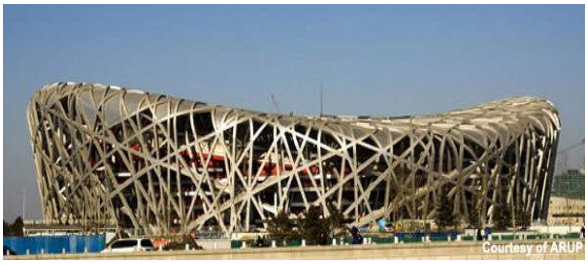
4.4 Council House Melbourne

The design of Council House Melbourne, by Mick Pearce, also uses ventilation strategy similar to termite mound using natural convection, ventilation stacks, thermal mass, phase change material and water for cooling. The façade is composed of dermis and epidermis which provide microclimate. Ventilation stacks are used on the north and south façade. The ceiling is wave like to optimize surface area to increase thermal mass capacity. The west façade is covered with system of timber louvers to optimize the penetration of natural light and views. Vaulted ceiling allows more filtration of natural light to the deeper parts of space. Shower towers provide reduction of 13 degree C from

top of the tower to the bottom. (City of Melbourne, 2010)

4.5 Beijing National Stadium

The Stadium is popularly known as Birds nest. The building has adopted "Cushion System' adopted where façade is in-filled with translucent ETFE panels just like nest is insulated by small pieces of material. The building protects spectators from nature, provides acoustic insulation and reduces maintenance cost, reduces dead load and filters sun.



The Nest-Beijing National Stadium

The examples in section 3 and 4 are enough to make a point the people are getting fruitful inspiration from nature for the area of their interest. Architects have also tried to get inspirations for design of their buildings. While taking inspiration we need to be careful o the aspect we are trying to learn. Some of the components of Bioinspiration have been listed here with in the coming section.

5.0 COMPONENTS OF BIOINSPIRATION

There are largely three key components of Bioinspiration:

1. The Form or Function
2. The Process and
3. The System

These are discussed briefly and can be elaborated by the individual trying to explore Bioinspiration for his design.

5.1 The Form or Function

The clearest component of Bioinspiration is emulating the shape or forms found in nature. While visiting nature we need to study the generator of the form that we like to

incorporate in our design. We need to review various shapes available in nature that could be useful for a particular function.

5.2 The Process

Following the process of nature is more difficult to be adopted for human activity. In case we wish to depend on nature for processes then we need to examine and learn how it is made in nature and requires collecting details of elementary processes that nature uses to generate.

5.3 The Systems

Adopting the natural system is the most complex level of Bioinspiration. The essential requirements is understanding and following the complex natural process in the design. In nature everything is inter-dependent, and replication of a natural system shall require complete study including the role of the dependent players and their involvement. The system may be where altogether different species profit from each other's waste or by-products, where the waste or by-products from one organization turns into a vital asset to one or a few of the other organizations. Different aspects of a system arrangement may incorporate collective utilization of infrastructure for energy, water and wastewater, and joint arrangement of services, for example, transportation, nourishment arrangement and fire containment.

6.0 BIO-INSPIRATION AND ARCHITECTURE: FUTURE POSSIBILITIES

Architects have been trying to adopt learning's from nature in their buildings to make them aesthetic, functional and long lasting-to fulfill the basic requirements of architecture. According to Whiteside's (2015) 'The enormous range of functional solutions to the many problems faced by living organisms guarantees that 'Bioinspiration' is a field that will continue to provide excellent science for many decades. At almost all levels of complexity and function—from 'simple' structures such as seashells (which are extraordinarily sophisticated heterogeneous composites designed to dissipate the energy of attackers trying to breach the shell) to the (currently) unassailably difficult problems of sentience and memory—biology provides examples of function at every level of complexity'. The examples given here amply prove the fact. The more we explore, we shall be finding solutions for a particular situation.

The species have been living and surviving for ages on this planet. They have learnt to live and survive in the changing environmental conditions. The species have learnt to live in extreme cold as well extreme hot conditions. You can find a species of cold environment living in extremely hot condition. This adaptability of specie in varied conditions inspires one to learn the process and adopt the same for the human being also.

Bioinspiration has tremendous opportunities of application in architecture. We shall find sustainable solutions to every problem from the species or processes in the nature. For example, sun is the only source of energy and is sustainable. Every species in nature depends on sun for light and energy requirements. We need to learn how to tap it in our buildings. There are examples of species living and surviving in hottest of the deserts. We need to learn their survival strategies. We need to learn how they fulfill their water requirements, the temperature management tricks and try to adopt similar processes in the buildings we design

7.0 CONCLUSIONS

Bioinspiration provides tremendous opportunity to a keen eye. Unfortunately, architects have been away from biology and it becomes difficult for they to follow the natural species. They also do not have sufficient patience to study and understand the nature. But nature is the biggest source of inspirations. It has inspired generations and shall keep on inspiring. We only need to develop an eye for Nature and its entire species. Unfortunately, it is time consuming and needs lots of patience.

The examples discussed here amply make a case the Bioinspiration has lots of promises for the Architects and they need to certainly take advantage. Going to nature is like going back to basics of the sciences and evolution. An architect can get inspirations from the forms and shape available in nature and its species, from the processes of nature evolve a process for his design. One can even learn from different part of the species to adopt the process in design. Nature in fact is the largest treasure house and has so much of variation that no two designs shall be similar, even if they are inspired by one species. Since biology is not the domain of architects, they shall have to involve the biologist in their practice for utilizing their expertise. This multi-disciplinary approach seems to be the only way forward if we wish to let this planet save from annihilation.

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