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Biomimicry-An Alternative Solution to Sustainable Buildings

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Abstract—*Conscious about nature and in a need to reduce their carbon footprint, architects today are constantly looking for innovative ideas for reducing, reusing and recycling energy in the field of architecture. Biomimicry, adopted by design professionals is an alternative solution to the traditional ways of viewing sustainable building design. Biomimicry can provide alternative solutions for various structural efficiency, water efficiency, zero-waste systems, thermal environment, and energy supply, which are essential for any sustainable building design. These solutions in many cases have solved the same problems with less energy and economy. This paper aims to explore the application of Biomimicry in architecture, and how nature inspired buildings can save resources and energy use. This paper also discuss about few animals and insects we can take inspiration from for research and development in various allied fields of architecture*

Biomimicry has since become a design discipline that investigates how the natural environment operates, and more specifically, how living organisms create and solve design challenges. Design solutions adapted through the use of Biomimicry are intended to foster a more sustainable human experience and existence. Major architectural design firms, in building and city design, are actively using this new discipline. The paper also attempts to study The Eden Project (2001), Cornwall, England, Norman Foster's Gherkin Tower (2003) and Lily pad a floating city as Biomimicry examples across the world and draw inferences of how to bring about a change in the built environment with respect to environmental concerns globally

1. INTRODUCTION

In order to explore and fulfill his desires, man has always exploited Nature and destroyed natural environment. This has resulted in some negative repercussions on the environment in which man lives – Global Warming. To curb the horrifying impacts of global warming people are aiming towards sustainable living. 'Sustainable' is a buzz word amongst various professionals these days including architects. Everyone wants a development that meets the need of the present without compromising the needs of future generations and having a minimal negative impact on nature.

Currently, buildings account for 40% of world's energy, and it is projected that in next decade 60% of world's population will be living in buildings in cities with a population of over one million. And world's energy is expected to grow more than 30%.1 In order to meet the required energy needs without further harming the nature, architects and other professionals are trying many different passive and active techniques in which they can switch from non renewable energy to renewable energy. Biomimicry2 is one such field in which architects in collaboration with biologists are finding solutions for sustainable development. Biomimicry is nothing new; it's just a forgotten wisdom. Through ages man has been mimicking the techniques of nature. He learned hunting, swimming and constructing better shelters for living from nature.

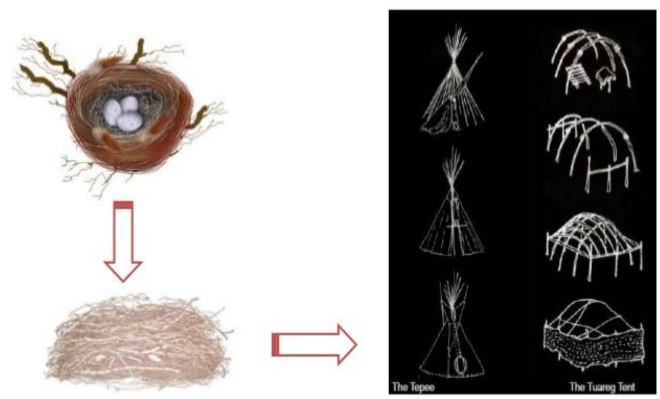

Fig. 1. 1: Concept of Biomimicry

Biomimicry is a discipline that refers to study of nature's best ideas and then imitate these designs and processes to solve human problems. We can look at nature like a big fat book of recipes from grandma, with a 3.8-billion-year of research period. And given that level of investment and development, it makes sense to use it. There are various examples to give a sense of what Biomimicry can deliver, such as invention of Velcro fastening from studying cocklebursx, the design of the Japanese Shinkansen bullet train nosecone, based on the beak of a kingfisher bird, invention of better solar cell studying a leaf, etc.

[1]Better health with plants-a forgotten wisdom
[2] Biomimicry is a term coined by biologist Janine Benyus

After many years of evolution, nature has evolved highly efficient systems for every challenge that we face today; it's all about exploring it and innovating these systems for a creative alternative to our traditional solutions. Nature knows what is best, what works and what lasts. Biomimicry is a crossroad between nature and technology. It introduces a revolution based not on what we can extract from our environment, but what we can learn and imitate from it in our design philosophies. It is not about using the microbes or any other organism in the process but to learn what it does.

2. HOW NATURE DOES IT - INSPIRATION WE CAN AND HAVE TAKEN FROM NATURE

2.1 What we learnt from honeybees

The best way to build a store house with maximum capacity and least amount of building material is derived from the hexagonal bee hive. This has also helped in making many homeless shelters. Hexagon has proven to be the most compact two dimensional shapes.

Fig. 1: BeeHive

2.2 Learning how to clean without cleaners from Lotus Leaf

Lotus leaf appears to be smooth as its water repelling, but rather it has a rough texture. Seen in microscope, the leaf has a rough structure that traps a maze of air on which the water droplets float and as a result self cleans the leaf.

Fig. 2: Lotus Leaf

A University professor at the University of Bonn in Germany has developed a surface based on the lotus leaf. This knowledge has lead to a new generation of paint, glass and fabric finishes all to minimize the use of chemical or laborious cleaning[3].

[3] Arnarson. P. O, (2011). Biomimicry

2.3 Learning from sharks how to make surface anti-bacterial

The patterns on Galapogos shark's skin denticles don't let the bacteria house its skin. The reason behind this is its unique pattern. This pattern prevents the bacteria to land and adhere. This unique feature of this slow moving shark was recognized by a company called 'Sharklet Technologies' which are using the same pattern on the surfaces in hospitals to impede bacterial growth.

Fig. 3: Galapagos Shark

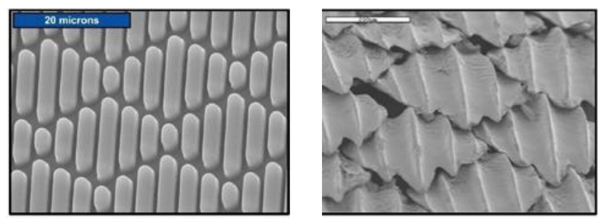

Fig. 4: Pattern derived from Galapagos Shark Skin

2.4 Learning from criter how to make water from fog:

The Namibian Beetle (Stenocara gracilipes) lives in Namib, Africa. Namib is one of the driest deserts in the world. But this beetle has evolved the best water harvesting technique from fog. This beetle has microscopic bumps on its wing corners. These bumps have hydrophilic (water loving) tips and hydrophobic (water repelling) waxy sides.

Fig. 5: Namibian Beetle (left) and Surface mimicking Namibian Beetle back (right)

The fog settles in its water loving bumps, and then water materialize and goes to the waxy side from which it slides down into its mouth. This technology could be used to generate clean freshwater in places like arid regions, refugee camps, etc. In-fact, one of the architectural firms, Grimshaw has created synthetic surfaces mimicking this beetle for harvesting fog water, which works 10 times better than any fog catching net.[4]

2.5 What we can learn from Spiders

There's a lot we can learn from Spiders. They have these spinneret glands (as shown on the image below) on the abdomen which produces six different types of silk, which is spun together into a fibre. This fibre is tougher than any fibre humans have ever made. The closest we've come is with aramid fibre, which is used in aerospace and military applications. And to make that, a lot of pollution is emitted as it takes loads of energy in its production. But, the spider manages to do it in harmony with nature, without destroying nature.

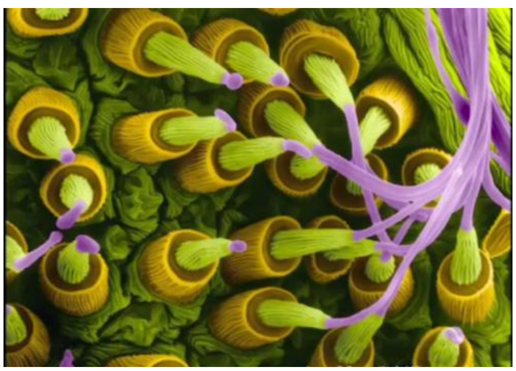

Fig. 6: Spinneret Glands of Spider

2.6 What we can learn from Charcoal Beetles:

Charcoal Beetles or the fire beetles, can detect a forest fire at 80 kilometers away. That's roughly 10,000 times the range of man-made fire detectors.5 These beetles have a special set of sensors which can detect infrared radiation, the invisible rays of heat given off by fires. Insect based fire alarms could be a revolution in disaster management industry.

Fig. 7: Fire Beetle

[4] Janine Benyus, 2009
[5]Michael Pawlyn, 2010

3. CASE STUDIES: BIOMIMICRY IN ARCHITECTURE AND BUILDING DESIGN

Biomimicry allows creating more intelligent and sustainable design through the emulation of nature. Designers and Architects are poised to take advantage from the integration of Biomimicry in their design process. Understanding this, the Biomimicry community developed a process; *'the design spiral'* which is a guide which helps 'biologize a challenge, query the natural world for inspiration, then evaluate to ensure that the final design mimics nature at all levels—form, process, and ecosystem.' The spiral form was chosen to 'emphasize the reiterative nature of the process.[6]

Integrating Biomimicry in design can be done in two different ways, taking place from design to nature or going from nature to design.

3.1 Eastgate Building: Learning from termites-- How to Create Sustainable Buildings?

The operation of buildings represents 40% of all the energy used by humanity, so learning how to design them to be more sustainable is vitally important. Sustainability is not exactly man-made, it can be learned from nature through construction techniques of Termites.

Fig. 8: Termite Nest

There's a common belief about termites as building destroyer. But that's not true. One example is the Eastgate Building, an office complex in Harare, Zimbabwe, which has an air conditioning system modeled on the self-cooling mounds of *Macrotermes michaelseni*, termites that maintain the temperature inside their nest within one degree, day and night (while the temperatures outside swing from 42 °C to 3 °C)[7].

Termites build their mounds using zero-waste construction methods, employing solar-powered air conditioning and developing a sustainable agriculture system.(Pawlyn, 2011) (Turner & Soar, 2008). The mound created by compass termites has the shape of a flattened almond with a long north-south axis that catches the light during the day and release heat during the night. Termites are able to open and close a series of heating and cooling vents throughout the walls of mound during the day. Hence, when interior temperature becomes too

[6] http://www.designboom.com/contemporary/biomimicry.html
[7-5] Biomimicry in Architecture by Michael Pawlyn, 2010

hot, vents can be opened; thus, rising warm air by stack effect. (Pawlyn, 2011) (Doan, 2012).

Having to learn that from termites, architect Mick Pearce, designed Eastgate Building, which uses 90% percent less energy for ventilation than conventional buildings its size.

Fig. 9: Eastgate Building

The solution was a passive-cooling structure with specially designed hooded windows, variable thickness walls and light colored paints to reduce heat absorption. The construction is based on a heavy masonry construction, which uses an external shading system that helps to minimize the solar heat gain. Furthermore the cool air is circulated into large floor voids that have a labyrinth of precast concrete elements that maximize heat transfer by having a large surface area. (Pawlyn, 2011) (Turner & Soar, 2008)

3.2 The Eden Project (2001), Cornwall, England

The Eden Project (2001) in Cornwall, England is a series of artificial biomes with domes modeled after soap bubbles and pollen grains. Grimshaw Architects looked to nature to build an effective spherical shape. The resulting geodesic hexagonal bubbles inflated with air were constructed of Ethylene Tetra-fluoro-ethylene (ETFE), a material that is both light and strong. The final superstructure weighs less than the air it contains.

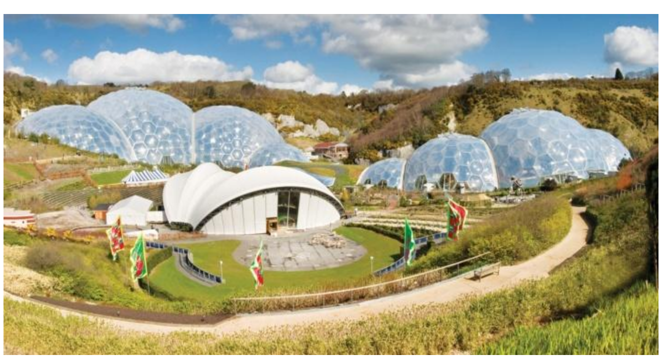

Fig. 10: Eden Project

Designed by Grimshaw Architects, it consist of two Biome (a biome is a large naturally occuring community of flora and fauna occupying a major habitat) - the Rainforest Biome and the Mediterranean Biome - each consist of several domes joined together, and are joined in the middle by the Link building. Grimshaw's starting point was the geodesic system made famous by the American architect Buckminster Fuller. The geodesic concept provided for least weight and maximum surface area on the curve – with strength[8].

Fig. 11: Eden Biomes took inspiration from Soap bubbles)

In the Eden Project domes, there are these geometric panels. In these panels there are the ETFE (**ethyl tetra fluoro ethylene)** pillows. Each pillow is attached to a web of interlocking steel tubes. Each dome actually has two web layers, one with hexagonal and pentagonal panels and one with triangular panels. The total Eden structure uses 625 hexagons, 16 pentagons and 190 triangles[9].

Fig. 12: Each ETFE pillow is secured in the steel framework.

3.3 Norman Foster's Gherkin Tower (2003)

Norman Foster's Gherkin Tower has a hexagonal skin inspired by the Venus Flower Basket Sponge. This sponge sits in an underwater environment with strong water currents and its lattice-like exoskeleton and round shape help disperse those stresses on the organism.

[8]https://www.edenproject.com/eden-story/behind-the-scenes/architecture-at-eden

[9] http://science.howstuffworks.com/environmental/conservation/conservationists/eden3.htm

Fig. 13: Gherkin Tower (left) inspired from Venus Flower Basket Sponge (right)

The Gherkin is essentially an elongated, curved, shaft with a rounded end that is suggestive of a stretched egg. It is sheltered uniformly around the outside with glass panels and is rounded off at the corners. It has a lens-like dome at the top that serves as a type of observation deck.

The design of the Gherkin is greatly steeped in energy efficiency and there are a number of features that enhance its efficiency. There were open shafts built in between each floor that act as ventilation for the building. The shafts pull warm air out of the building during the summer and use passive heat from the sun to bring heat into the building during the winter. These open shafts also allow available sunlight to penetrate deep into the building to cut down on light costs.[10]

3.4 Lily pad a floating city

The Lilypad, by Vincent Callebaut, is a concept for a completely self-sufficient floating city planned to provide shelter for future climate change refugees.

Fig. 14: Lilypad, Floating City

[10] http://www.designbookmag.com/thegerkin.htm

We see Biomimicry as the inspiration behind the design of the city. The Lilypad, which was designed to look like a waterlily, is proposed to be a zero emission city afloat in the ocean. Through a number of technologies (solar, wind, tidal, biomass), it is envisioned that the project would be capable of not only producing it's own energy, but also will process CO2 in the atmosphere and absorb it into its titanium dioxide skin[11].

Fig. 15: Inspiration from WaterLily

The Noah's Ark project features a series of terraced rings with deep underwater towers that act as ballasts to increase stability. The innovative project would support life on terraced fields, provide ample space for food growing, collect rainwater and generate its own power through natural energy sources such as solar, wind and wave energy, which are easily captured at sea

4. COMPILATION OF FEW EXAMPLES

Name of building	Inspiration	Application in design
Eastgate Centre, Harare, Zimbabwe	Termite mound	The building is designed with a distinctive ventilation system, which draws outside air and cools or warms it depending on temperature.
Eiffel Tower, Paris	Thigh bone	The outward flares at base resemble the upper curved portion of femur. The internal wrought iron braces closely follow design of original trabeculae within femur.
Beijing National Stadium	Bird's nest	"Cushion system" adopted where façade is in-filled with translucent ETFE panels just like a nest is insulated by small pieces of material.

[11] Bob in the Sea in This Untethered 'Lily Pad' City of the Future Monday, November 5, 2012, by Amy Schellenbaum

Habitat 2020, China	Stomata of leaves	The exterior designs as living skin which serves solves linking between exterior and interior, like stomata on leaf surface. The surface automatically positions itself according to the sunlight. Surface absorbs water and converts waste to biogas energy.

5. CONCLUSION

Although Biomimicry is a new field and is likely to have a great impact on sustainable architecture. It is one of the fields where architects, biologists, environmentalists, etc can all work together for a better sustainable living. The built environment is increasingly held accountable for global environmental and ecological troubles with enormous magnitude of waste, materials and energy use and green house gas emissions attributed to the habitats humans have created for themselves (Mazria, 2003, Doughty and Hammond, 2004).

It is becoming progressively clearer that a change has to be made in the built environment with respect to environmental concerns globally. Mimicking ecosystems are one readily available example for humans to learn from and an inspiring prospect for future human habitats. By using a framework as recommended and shown by this paper it is likely that distinctions between the different kinds of Biomimicry and their regenerative possibility can be more easily made.

An architectural design example that succeeds in mimicking the ecosystems are able to function in a sustainable and even regenerative way also has the potential to completely change the environmental scenario of the built environment in the present day context.

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