Journal of Civil Engineering and Environmental Technology
p-ISSN: 2349-8404; e-ISSN: 2349-879X; Volume 3, Issue 5; April-June, 2016, pp. 416-421

http://www.krishisanskriti.org/Publication.html

# Biological Inspirations in Innovative Design

**Premlata Gupta**

*School of Architecture Galgotias University Greater Noida*
*E-mail: premlatagupta17@gmail.com*

**Abstract—***Human beings have looked at nature for answers to problems since ages on Mother Earth. Biomimicry or biomimetics is an approach to innovation and creativity by incorporating sustainable ideas from nature's mechanisms, patterns and strategies. It taps nature's huge reservoir of structures, process optimizations and functional solutions in order to find technical applications of natural principles. Biomimicry in Architecture defines it as 'mimicking the functional basis of biological forms and systems to produce sustainable solution. It encourages us to approach nature with modesty and conduct an in-depth study about the systems to extract design principles, apply the same and innovate in a manner aligned to the planet. This paper presents some recent developments and perspectives about the use of biological inspiration in innovative design to create energy efficient and sustainable systems by material optimization, zero waste,etc.*

**Keywords***: Biomimicry, sustainable systems, energy efficient, material optimization, zero waste*

## 1. INTRODUCTION

Biomimicry or biomimetics is an approach to innovation and creativity that urges to incorporate sustainable ideas using nature's oldest mechanisms, patterns and strategies. In even simpler words, it is the imitation of the various elements of nature to solve mankind's complex issues. In the 1950s, American biophysicist and polymath Otto Schmitt came up with the concept of Biomimetics. It was during his doctoral research, while he was studying the nerves in a squid, that he developed the Schmitt Trigger and attempted to create a device that replicated the biological nerve system. The term Biomimicry appeared in the year 1982 and was popularised by author and scientist Janine Benyus in her book – Biomimicry: Innovation Inspired by Nature. Biomimicry is defined in the book as a "new science that studies nature's models and then imitates or takes inspiration from these designs and processes to solve human problems" [1].

Biomimicry is relevant and applicable at various scales, from non-toxic adhesives that emulate the micro-structure of hair on a Gecko's foot, to a high-rise building that emulates a termite mound's ventilation system for thermal regulation and possibly to urban scale systems that mimic forest eco-systems. The optimization of resources and energy efficiency that took place in the evolution of all biological systems is of special interest [2]. Nature has solved several engineering problems such as self-healing abilities, environmental exposure tolerance and resistance, hydrophobicity, self-assembly, and harnessing solar energy. Thus Biomimicry is a scientific design discipline where patterns and strategies found in nature are emulated/ mimicked to find sustainable and better solutions to human challenges.

Numerous associations of Biomimicry, practitioners interested in the approach were created: BIOKON (Germany), the Biomimicry Institute (co-founded in the US by Benyus), Biomimicry Europa (Belgium and France), and Biomimicry NL (Netherlands), Biomimicry IL (Israel), Biomimicry UK & Biomimicry India Network. Biomimicry, where flora, fauna or entire ecosystems are emulated as a basis for design, is a growing area of research in the fields of architecture and engineering. This paper presents some examples of biologically inspired product and recent developments and perspectives about the use of biological inspiration in innovative design.

## 2. GRADES OF IMPLEMENTATION OF BIOMIMICRY.

In an attempt to invite solutions for sustainability, Biomimicry guides us to engage in an intense conversation with nature and simulate what we learn on three levels [1].

**A. Natural Form or Organism level**- (Mimicry of a specific organism)

The first level of biomimicry is the mimicking of **natural form**. It is also referred to as organism level, which involve mimicking part of or the whole organism a plant or animal as seen in Norman Foster's Gherkin Tower, its hexagonal skin is inspired from flower basket sponge.

**30 St Mary Axe: The Gherkin in London.** The Gherkin Tower designed by famed architect Norman Foster in London, is 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 which were applied to Foster's design of the tower. The deep sea Venus' Flower Basket sponge and its efficiency in filtering water and nutrients inspired designers of the Gherkin. Gaps in each floors create shafts that sandwich air between the two layers of spiralling glass that encase the building, which keeps the Gherkin insulated.

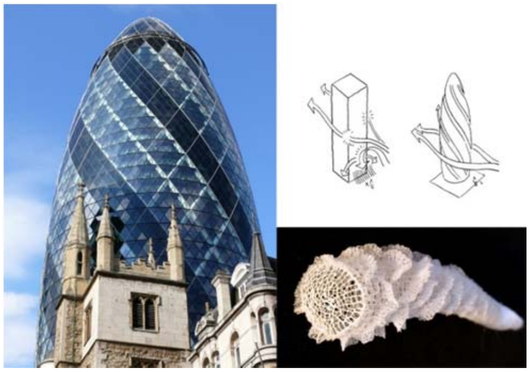

**Fig. 1: Gherkin Tower**

**The Eden Project Cornwall, England.** Designed by Grimshaw Architects, the two Biome buildings – the Rainforest Biome and the Mediterranean is a series of artificial biomes with domes modelled after *soap bubbles and pollen grains.* Grimshaw Architects looked to nature to build an effective spherical shape, resulting in geodesic hexagonal bubbles. It is inflated with air and constructed of Ethylene Tetrafluoroethylene, a material that is both light and strong. Studying *pollen grains, radiolarian and carbon molecules* helped them to devise the most efficient structural solution using hexagons and pentagons [3].

**Fig. 2: The Eden Project**

**Esplanade - Theatres on the Bay, Singapore.** Esplanade Theatres on the Bay is better known as "the Durian", because of its shape. The Esplanade theatre and commercial district in Singapore by DP Architects and Michael Wilford hosts an elaborate skin inspired by the Durian plant. The external shading system is also responsive in that the triangular louvers adjust during the day to the suns angle and position.

**Fig. 3: The Esplanade, Singapore**

**Sharkskin Swimsuit.** Sharkskin-inspired swimsuits received a lot of media attention during the 2008 Summer Olympics. It is made up of countless overlapping scales called dermal denticles (or "little skin teeth"). The denticles have grooves running down their length in alignment with water flow. These grooves disrupt the formation of eddies, or turbulent swirls of slower water, making the water pass by faster.

**Fig. 4: Sharkskin swimsuit (left) & Mosquito needle (right)**

**Mosquito Needle.** Materials researchers and engineers at Kansai University in Japan saw amazing potential in the structure of the mosquito's mouth. They used sophisticated engineering techniques to make a needle that penetrates ike a mosquito, using pressure to stabilize and painlessly glide into skin. [6]

**Humpback Whale - wind turbine.** A humpback whale swims in circles tight enough to produce nets of bubbles. It turns out that the whale's surprising dexterity is due mainly to its flippers, which have large, irregular looking bumps called tubercles across their leading edges. A company called *Whale Power* is applying the lessons learnt to the design of wind turbines to increase their efficiency [6].

**Fig. 5: Humpback Whale - wind turbine**

### B. Natural Process or Behavioural- (Mimicry of how an organism *behaves or relates* to its larger context)

Deeper biomimicry adds a second level, which is the mimicking of natural process, or how a thing is made. It refers to mimicking behaviour, and includes translating an aspect of how an organism behaves, or relates to a larger context. Building mimics how the natural form or organism interacts with its environment to build a structure that can also fit in without resistance in its surrounding environment.

**Hydrophobicity and self clean.** The famous example is the lotus leaf which grows in a muddy area, and yet it's very clean. The fine microstructure of the leaf induces water to form tiny beads that roll off the surface taking dirt along with it. The dry facade paint called Lotusan has that bumpy structure like lotus leaf so that rainwater cleans the building, instead of sandblasting or detergents.

**Fig. 6: Hydrophobicity (left) & Bug Eye (right)**

**BAE Systems' 'Bug Eye' technology.** Alex Parfitt's team at BAE Systems took inspiration from a 4mm bug – the Xenos peckii – which have 50 separate lenses each creating a separate image that are stitched together to give a single, large panoramic view. The result is a vision system of multiple lenses small and light enough to fit inside a soldier's helmet while doubling the field of vision.

**Eastgate Center.** Designed by Architect Mick Pearce, Eastgate Building is an office complex in Harare, Zimbabwe, which has an internal climate control system originally inspired by the structure of termite mounds. Modelled on the way that termites construct their nest to ventilate, cool and heat it entirely through natural means, Eastgate's ventilation system costs 1/10th that of a comparable air-conditioned building and uses 35 per cent less energy than comparable conventional buildings in Harare [5] . A combination of in situ concrete and double thickness brick in the exterior walls moderates temperature extremes, and generally light coloured finishes reduce heat absorption.

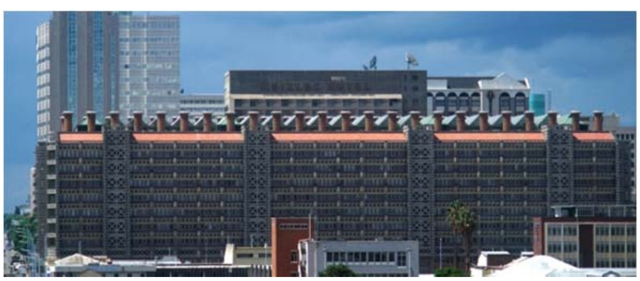

**Fig. 7: Eastgate Center**

**Qatar Cacti Building.** Designed by Bangkok-based aesthetics Architects, the Qatar Cacti building uses the cactus's relationship to its environment as a model for building in the desert. 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. The project reaches out to the ecosystem level in its adjoining botanical dome whose wastewater management system follows processes that conserve water and has minimum waste outputs.

**Shimkansen Bullet Train.** Eiji Nakatsu, the Shinkansen 500 train's chief engineer and an avid bird-watcher, modelled the front-end of the train after the beak of kingfishers, which dive from the air into bodies of water with very little splash to catch fish. The result was a quieter, 10% faster and 15% more efficient train [5].

**Fig. 8: Qatar Cacti Building**

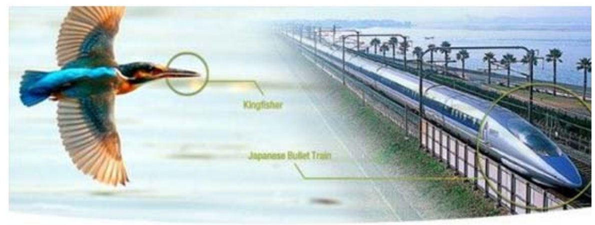


**Fig. 9: Bullet Train**

**C. Natural System or Ecosystem- (Mimicry of an Ecosystem)**

It involves mimicking of how the environments and its components work together as a large project with multiple elements rather than a solitary structure.

**Cardboard to Caviar Project.** The Cardboard to Caviar Project founded by Graham Wiles in Wakefield, UK is a cyclical closed-loop system using waste as a nutrient. The restaurant pays Mr Wiles to take away their cardboard boxes, which he then shreds; the Stables pay Mr Wiles to provide them with horse bedding, ideally shredded cardboard; the Stables then pays Mr Wiles to take away the spent horse bedding, which he then feeds to worms to compost; the worms are then fed to Sturgeon, which produce caviar. This is the most expensive stage in the cycle; the restaurant then pays Mr Wiles for his high end caviar, and also to take away their cardboard boxes. Thus he identified a path of operations emerging from a common waste product (cardboard boxes) and turning it into a high value end product (caviar), which could be sold back to the original producer of waste [8].

**Lavasa India.** The city of Lavasa situated near the Mumbai Pune economic corridor, is designed as a set of five urban towns set in the valleys and slopes of the seven surrounding hills that will mimic its dense forest. Despite the heavy rains, the steep hills suffer almost no erosion. Biologists from Biomimicry 3.8 studied the area's ecosystem. Then they developed a set of design recommendations and ecological performance standards to ensure that whatever gets built performs at the same level as the natural environment. The roofs help re-release the rain water back into the air as water vapour. The pavement allows water to permeate back into the ground and building foundations that grip the hillsides like the roots of trees. To design roads, the team took inspiration from *local anthills* that are able to remain structurally sound during the region's heavy rains. Using trees as the design principle, HOK designed a building foundation system that stores water, just like the *trees that once existed*. [10].

**Fig. 10: Lavasa, Maharastra, India**

Thus by applying biomimicry at all three levels—natural form, natural process, and natural system, we'll begin to create conditions conducive to life.

## 3. APPROACHES TO DESIGN SUSTAINABLE SYSTEM

Michael Pawlyn describes three habits of nature that could transform architecture and society: radical resource efficiency, closed loops, and drawing energy from the sun.

### a. Resource Efficiency

Resource efficiency means process optimization to limit consumption of energy, water and materials and output of waste products. Biomimicry offers completely new ways of approaching design to radically increase resource-efficiency.

**Bone shoe heel.** Dutch fashion designer Marieka Ratsma and American architect Kostika Spaho used the shape of a *bird's cranium* for the front of the shoe, with the tapered beak as the spike of the heel to make a lightweight and efficient structure.

**Fig. 11: Bone Shoe (left) & Go Chair (right)**

**Ross Lovegrove Go chair.** The 3D printed Go Chair that fits naturally to the human form uses organic shapes and lines to create seating with ultramodern materials like Magnesium.

**Wilfredo Mendez's Earthquake Resistant Structure.** The *femur is the strongest human bone* and its hollow cylinder design provides maximum strength with minimum weight. In order to achieve the bio-structural adaptation, hollow-shaft columns and beams are used whose morphology was adapted to its bending moment diagram. The design encourages the efficient concrete utilization and building weight reduction. Thus the building seismic vulnerability was significantly reduced, increasing its adaptation to the site characteristics.

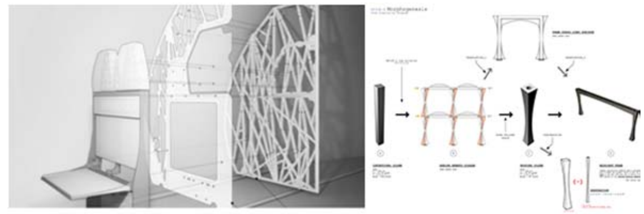

**Fig. 12: Femur structure (left) & Airbus (right)**

**Airbus- partition systems.** The Airbus Group is taking innovation inspired by nature to the air by using 3D printing to help build a stronger, lighter-weight galley partition that mimics *cells structure and bone growth*.

### b. Linear to closed loop ecosystem

In this approach the system functions as a closed loop, meaning all by-products of one organism's actions are utilized as fuel energy for another organism's needs.

**Mobius Project- London's Old Street.** Michael Pawlyn's Mobius project is a concept based on closed loop that would transform the London's Old Street roundabout that would include a greenhouse, restaurant, aquaculture, and composting, mushroom cultivation and food market. It is a restaurant in a greenhouse where food scraps are composted to produce heat and electricity. Waste water is treated by plants and microorganisms to become fresh water. Fishes are raised on compost and worms and eventually served in the restaurant. A cafe would recycle its coffee grounds to grow mushrooms to also feed into the restaurant [11]. If we could utilize the waste generated by humans as a resource instead of hiding, burning or burying it, we would protect the environment and save resources.

**Fig. 2: Mobius Project (left) & Morarjee Textile (right)**

**Morarjee Textiles -zero-waste textile factory.** The UK based Exploration Architecture team conceptualized a structure that radically reduces waste in the resource-intensive production of textiles. Smart use of resources is at the centre of the design, and inspiration from nature is the root of the water and energy system for the textile factory. Designs for the building itself were inspired by the *Euplectella glass sponge* [4]. That structure led to the design of a lightweight roof that integrates structure, solar power harvesting, and allows for natural light to filter into the building.

### c. Renewable Economy

Solar radiation is the only input into the closed loop ecosystem of earth and the only source of energy either directly or indirectly available to organisms. Nature's designs inspire technological innovations which offer promise for "bio inspired energy" to create more efficient energy production, energy storage, and energy delivery with innovations that replicate the designs of natural systems.

**Sahara Forest project - Beetle.** The Sahara Forest Project designed by the firm Exploration Architecture is a greenhouse that aims to rely on solar energy alone to operate as a zero waste system. The project mimics the *Namibian desert beetle* to combat climate change in an arid environment. It draws upon the beetle's ability to self-regulate its body temperature by accumulating heat by day and to collect water droplets that form on its wings. The greenhouse structure uses saltwater to provide evaporative cooling and humidification. The evaporated air condenses to fresh water allowing the greenhouse to remain heated at night. This system produces more water than the interior plants need so the excess is spewed out for the surrounding plants to grow. The Sahara Forest Project is a scheme that aims to provide fresh water, food and renewable energy in hot, arid regions as well as re-vegetating areas of uninhabited desert [11].


**Fig. 14: Sahara Forest project**

**Saltwater greenhouse, Qatar.** Sahara Forest Project's first pilot facility was built in Qatar. It is a greenhouse structure that enables the growth of crops in arid regions, using seawater and solar energy. The technique involves pumping seawater to an arid location and then subjecting it to two processes: first, it is used to humidify and cool the air, and second, it is evaporated by solar heating and distilled to produce fresh water. Finally, the remaining humidified air is expelled from the greenhouse and used to improve growing conditions for outdoor plants [12]. The SFP Pilot in Qatar featured: Concentrated Solar Power, Saltwater greenhouses, Outside vegetation and evaporative hedges, Photovoltaic Solar Power, Salt production, Halophytes and Algae production.

**Fig. 15: Saltwater greenhouse**

**Metal that breathes- Bloom.** Doris Kim Sung works with thermo-bimetals smart materials that act more like *human skin*. Bloom a 20-foot canopy installed at the Materials & Applications gallery in Los Angeles is a *thermo-bimetal*, a laminate building material that changes shape as temperatures rise and fall. It is made primarily out of a sheet metal that curls when heated, the form's responsive surface shades and ventilates specific areas of the shell as the sun heats up its surface.

**Fig. 16: Bloom Project**

## 4. CONCLUSION

We know that Biomimicry is a rather young field of subject, but is very likely to have a great impact on our society in the future, as a new way of thinking bringing forward a sustainable solution harmonizing with nature. While Biomimicry is getting better known by societies around the world, the biologists are also getting their seat at the designing table. As a result the solutions in those projects they participate in are moving humanity closer to Nature. As shown in the examples of Biomimicry, the solutions are out there and by looking at nature as a model and mentor they can be applied and simulated in various fields.

Aimed at architects, urban designers and product designers, "Biological Inspirations in Innovative Design" looks to the natural world to seek pointers as to how we can achieve radical increase in resource and energy efficiency. Bundled with inspiring case studies predicting future trends, the main approaches look in turn at: structural efficiency; material manufacture; zero-waste systems; water; energy generation; the thermal environment; and biomimetic products. This is due to both the fact that it is an inspirational source of possible new innovation and because of the potential it offers as a way to create a more sustainable and regenerative built environment and a restorative future.

## REFERENCES

[1]. Janine M Benyus,(2002) Biomimicry: innovation inspired by nature, Harper Collins Publishers, ,New York
[2]. Biomimetics in Architecture (2009) evolutionary construction and design; International BIONA Symposium Stuttgart, Germany organised by *Institute of Building Structures and Structural Design*
[3]. https://www.edenproject.com
[4] TED Talk: Michael Pawlyn – Using nature's genius in architecture
[5].Biomimetic- Architecture (http://biomimetic architecture.com/)
[6]. Biomimicry 3.8(http://biomimicry.net/)
[7]. Sculpting Magnesium: A Masterpiece in Furniture Design, 2007
[8]. http://algalbiomass.weebly.com/graham-wiles-cardboard-to-caviar.html
[9]. **B**io-Structure Bone-Inspired Building Frame by Tectonica
[10]. A city in Making - Buildotech Magazine
[11]. http://www.exploration-architecture.com
[12].http://saharaforestproject.com/concept.html