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Biomimicry in Architecture; a Study of Historic and Modern Precedents

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Abstract: *Biomimicry is a practical concept, which provides sustainable approaches to solve human problems, by inspirations drawn from nature. It is a practice that learns from and mimics the strategies used by species alive today as well as other features in natures. The goal is to create products, processes, and policies (new ways of living) that are sustainable, solve our greatest design challenges and support all life on earth. Before the wide spread of the concept of biomimicry it has been evident throughout history that practices similar to the concept, such as designs inspired by nature have been in existence. One of such examples is the first air plane model designed by Leonardo da Vinci which was inspired by the flight of birds.*

This paper seeks to reveal similar examples of nature inspired designs in architecture of past Egyptian and Greek civilizations, by searching and analyzing secondary data from historic texts and documents. This study doesn't only help us identify and relate such examples to the present concept of biomimicry but also gives us a better understanding of concept of biomimicry in architecture by pointing out what ancient practices lacked, that the modern concept of biomimicry takes care of.

Key Word*: Biomimicry, Architectural history, Egyptian architecture, Greek architecture.*

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I. Introduction

Through history, man has looked to nature for solutions to his problem, historic records and observation of various manmade structures and inventions, especially in Architecture reveal significant developments contributed by the study and observation of nature. Such historical studies help us understand what is, from what was.

In recent times, the adverse deterioration of the environment due to climatic changes experienced globally, resulting from years of human interference with the natural environment through the consumption of fossil fuel, has led to a call for more sustainable approaches to modern living conditions, hence the adoption of various approaches of sustainability to better improve climatic conditions. Many of this approaches and ideas point to one fact; that nature itself has been the bedrock of sustainability. With a continuous process of modification, whatever was not successful simply died out. One of such ideas is the concept of Biomimicry.

In 1997 biologist and science writer Janine Benyus popularized the term biomimicry, when she wrote the book Biomimicry—Innovation Inspired by Nature. 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.

The concept of biomimicry which is centered on practical lessons from nature provides a guide for more efficient solutions to human problems from a large collection of nature's efficient systems strategies and models, built over billions of years. The concept of biomimicry has been applied to various aspects of manufacturing and construction to produce outstanding results.

In architecture, many biomimetic structures have recorded such tremendous achievements as;

- Reduced negative climatic impact,
- Increased energy efficiency,
- Reduced cost of construction
- Aesthetically appealing facades

This paper seeks to reveal close examples of the concept of biomimicry in Architectural history before the concept of biomimicry was ever coined and to determine what such examples lacked by what modern examples of the concept were able to capture.

II. Egyptian Architecture

EGYPTIAN ARCHITECTURE:

The Egyptian civilization has long been regarded as the most conservative ever. Spanning over two thousand years, ancient Egypt was not one stable civilization but is divided into dynasties of rulers beginning with the fourth dynasty, shortly after 3000 B.C [5]. Egyptian art and architectural practices were govern by religion, believes and Egyptian cultural practices.

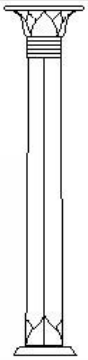
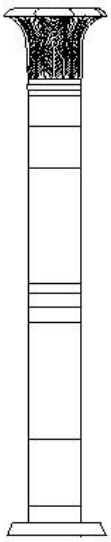
The best known example of ancient Egyptian architecture are the Egyptian pyramids while excavated temples, palaces, tombs and fortresses have also been studied. Most buildings were built of locally available mud brick and limestone by levied workers. Monumental buildings were built via the post and lintel method of construction. Many buildings were aligned astronomically. Columns were typically adorned with capitals decorated to resemble plants important to Egyptian civilization, such as the papyrus plant.

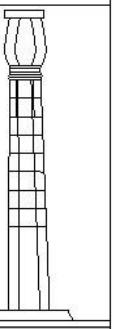
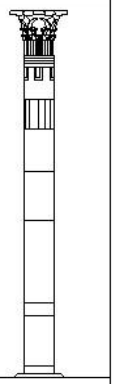
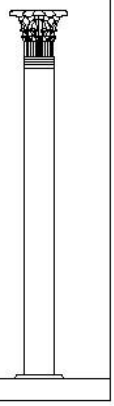
III. Egyptian Columns:

The Egyptian trabeated building system encouraged the vast use of columns as vertical elements, especially for temples and palaces. Most Egyptian columns built, were adorned with capitals which were made to resemble plants important to Egyptian culture, such as the papyrus, lotus and palms.

The use of columns in Egypt is said to have begun with square pillar, a practice that was adopted from the use of square pillars to support the roof of stone quarries [10]. According to john gardener Wilkinson, the depiction of natural features first started as surface paintings on walls and square columns, the next process in decorative art; that of chiseling in the relief was introduced later on. Ornamental elements like the lotus blossom, the papyrus head, palm, water plant, and a goddess head were among the usual design elements illustrated on walls, and later continued to be illustrated in the relief when an improved style of art had replaced painting with sculpture. The square pillar had been gradually converted into a polygonal shape, the ornamental devices not having room enough on its narrow facets led to the invention of another form of column; and from that time, a round shaft was surmounted by a palm tree capital or by the blossom, or bud of a papyrus plant. Hence, the new orders of columns was born. The various types of nature inspired design columns which feature in the Architecture of ancient Egypt are shown in table 1. According to the plant type they are modelled after [10]. These however are not all the types of Egyptian columns that exist, as columns such as the Osirid columns, the Hathor columns and the protodoric style columns have been left out due to the fact that they do not fit into this study context.

table 1. table showing the various plant form Egyptian columns

PAPYRIFORM COLUMNS			
COLUMN	**DESCRIPTION**	**NATURAL MODEL**	**2D DRAWING**
OPEN PAPYRUS COLUMNS  Capitals of ancient Egyptian columns decorated to resemble papyrus plants. (at Luxor, Egypt) source: wikipedia.org	there are many forms of papyrus columns made by the ancient Egyptians, some in circuar form from representing a singe plant while others are ribbed with multiple stems. the capitals were closed buds or open bell shaped form. they were amply used in the middle kingdom. open papyrus columns had capitals in bell shapes, with circular shafts. although earlier versions had square shafts and were not constructed from monolitic blocks.	 **PAPYRUS PLANT**	
CLOSED PAPYRUS BUD COLUMN  closed papyriform column source: trekearth.com	closed papyrus columns had ribbed shafts to represent multiple stems bound together. the capitals were closed papyrus buds		
PALMIFORM COLUMNS			
PALM LEAVE COLUMN  Egyptian column with palmiform capital. source: etsy.com	The Palmiform Columns were one of the earliest styles of columns in Egyptian temple architecture. Examples of this type of column were found, for example, in the 5th Dynasty pyramid mortuary complex of Unas. However, after the 5th Dynasty, these types of columns are rare, but continued to occasionally be used. Mostly we find examples during later periods at the Taharga temple in Kawa in Upper Nubia, and in some temples dating to the Graeco-Roman Period. However, they may also be found in the courts of the Ramesseum. These columns obviously had a palm tree motif, but did not actually represent the tree itself, but rather eight palm fronds lashed to a pole.	 **EGYPTIAN PALM**	

LOTIFORM COLUMNS			
COLUMN	**DESCRIPTION**	**NATURAL MODEL**	**2D DRAWING**
PAPYRUS CAMPANIFORM COLUMNS 	althought they sometimes apear in religious architecture, lotiform columns were not popularly use in temples , they were used majorly in the old and middle kingdoms, this columns had ribed capitals which tapper at the top till it hitts the abacus, the capitals are connected to the shaft with decorative bands resembling a rope used to hold bundles of reeds together. the shafts are alo ribed, and sometimes tapper at the lower end where they are attached to a circular base.	 LOTUS PLANT	
CAMPANIFORM COLUMNS			
PAPYRUS CAMPANIFORM  campaniform column in the form of bundled papyrus plant source: traveltoeat.com	campaniform column capital look alot more complex that the regular bell shaped papyrus or lotus column capitals. they all had some form of flower shaped capital, with shafts which were circular, ribed or square shaped.Two of the best known of these are located in the Hall of Annals of Tuthmosis III at Karnak. At this temple, the structures take the shape of a pillar. They include two styles of columns, with one representing the heraldic plant of Lower (northern) Egypt, the Papyrus, and the other type representing the symbolic plant of Upper (southern) Egypt, the Lotus.	NO PARTICULAR MODEL	
COMPOSITE COLUMNS			
PALM AND LOTUS COMPOSITE 	composite columns were probably an evolutionary extension of the campaniform columns, they had capitals designed with combinations of the various plant types which existed in previous column types, and became so utterly sylized that the original floral motifs could hardly be recognized.	NO PARTICULAR MODEL	

IV. Ancient Greek Architecture:

The Architecture produced by the ancient Greeks still stands out as one of the most influential styles of Architecture even till present date. Best known for its column orders, detailed ornamentation inspired by myths and religion, and the application of the concept of Architectural beauty based on balance and proportions. Some Greek works of art and architecture were however carefully crafted to depict natural features such as plant and animals. A typical example of such is the columns of the Greek Corinthian order.

V. Corinthian Columns:

The Greek Corinthian capital was invented in the fifth century, as an elaborate substitute for the ionic order; its shape is that of an inverted bell, and the curly ornamental details on the capital is inspired by the leaves and shoots of the acanthus plant which seem to sprout from the top of the column shaft. The earliest known instance of the use of Corinthian columns in Greek architecture is the monument of Lysicrates in Athens

built shortly after 334 B.C [5]. The Corinthian column will go on to future in the architectural style of different eras, such as Roman architecture, Gothic architecture, baroque Architecture, Neo classical architecture etc., in buildings of various purposes.

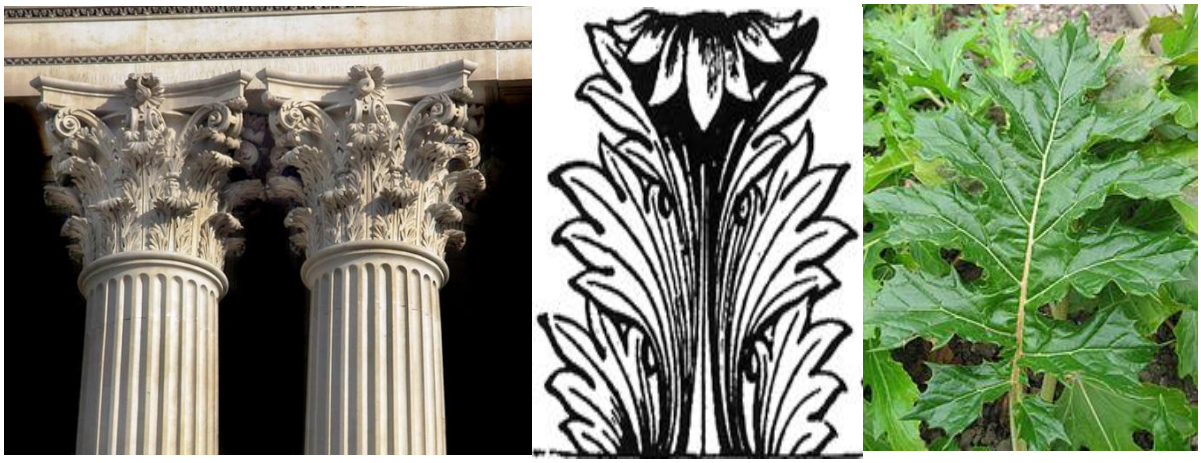


FIG 1: Corinthian column and capital Taken at St Paul's Cathedral, London. [2]

VI. Discussion:

According to the Biomimicry Institute, biomimicry can be defined as "an approach to ***innovation*** that seeks ***sustainable*** **solutions** to ***human challenges*** by ***emulating*** nature's time-tested ***patterns and strategies***. Judging by the key words in this definition, which are innovation, sustainable solution, human challenges, emulating nature's patterns and strategies. An ideal biomimetic design is done consciously and intentionally, has a degree of sustainable outcome, addresses a human, design, or engineering problem in one way or the other, employs natural systems, forms and strategies to solve such problems. The following examples discussed in the subsequent pages show how the concept biomimicry described in the above definition has been applied in modern architecture to various projects were the results were not just mere aesthetically appealing structures, but structures that present additional advantage in areas such as energy consumption, structural mass. Air conditioning systems, lighting systems, etc.

1. East Gate Center, Harare, Zimbabwe

Architect mick Pearce's Eastgate center, Harare, Zimbabwe, uses the ventilation system in the self-cooling mounds of African termites to create a low-cost cooling and air conditioning system in a mall and office complex. The East-gate center solves the problem of heating, cooling and ventilation which is often experienced in Glass office blocks which are typically expensive maintain at a comfortable temperature, needing substantial heating in the winter and cooling in the summer. They tend to recycle air, in an attempt to keep the expensively conditioned atmosphere inside, leading to high levels of air pollution in the building. Apart from these, the cost of maintaining such systems are expensive.

Cool air enters through the lower parts of the building and is circulated by fans, the air becomes warmer and lighter as it rises through the various floor of the building, and finally escapes through chimneys at the top of the building. The natural system helps reduce energy consumption by 10% when compared to a standard

building. Termites aren't the only inspiration from nature in this building, Architect mick pierce also designed the building façade to mimic a cactus plant. ''One of the ways that a cactus can resist high temperatures is that its many wrinkles, ridges and spikes increase its surface temperature. That makes it easier to disperse its heat at night. The Eastgate building borrows this idea too, with facades broken up by concrete shapes and projections, deep balconies and plants'' [8]

2. Beijing National Stadium, Beijing

The Beijing National Stadium, popularly known as the bird's nest, was designed by Swiss Architects Herzog & de Meuron in 2008 for the Olympics. The building façade was designed to mimic a bird's nest (upturned). The project consists of two independent structures, standing 50 feet apart, the red concrete sitting bowl. And the outer steel frame, designed to mimic twigs of a birds nest. Similar to how a nest is insulated by stuffing material between the twigs, the façade is filled with ETFE (Ethyl tetrafluoroethylene) panels to protect spectators, provide acoustic insulation, reduce the dead load on the roof and optimize the entry of sunlight [1].

Fig 3: Beijing National Stadium (Bird's Nest) [11]

3. Eden Project, England

Eden Project in England holds the record of the world's largest greenhouse. The huge dome shaped models fused together were designed to mimic soap bubbles. The efficient structural system consisting of hexagons and pentagons were derived after studying pollen grains, radiolaria, and carbon molecules. The biomes were made of ETFE (Ethyl tetrafluoroethylene) and steel. The geodesics are self-cleaning and act as a thermal blanket that traps air between them, resulting in reduced energy consumption. [1].

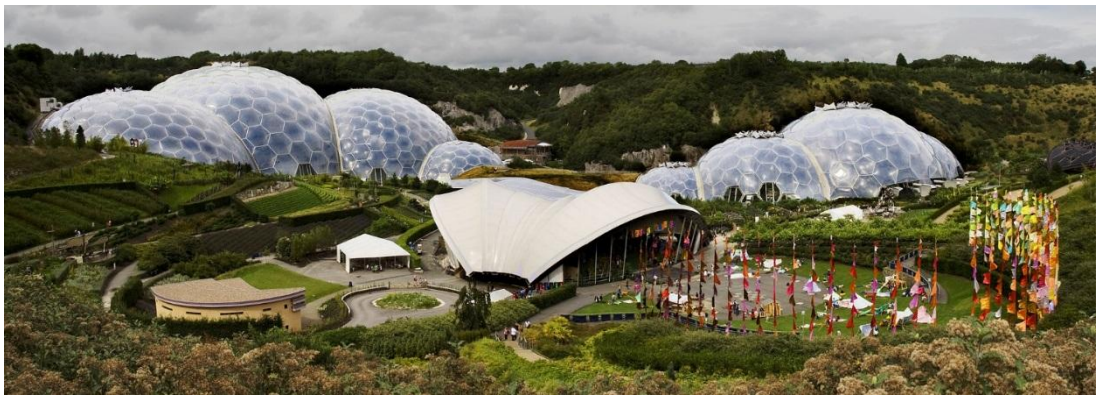


Fig4: The Eden Project in Cornwall. [12]

4. The Gherkin, London

The Gherkin tower, design by Architect Norman Foster mimics the shape and lattice structure of the Venus Flower Basket Sponge. This sponge has adapted to with stand a high amount of stress generated by water currents in its environment, by developing a lattice-like exoskeleton. Its round shape also helps to disperse the stress from moving water current in various direction. The lattice exoskeleton and shape of the sponge provides

strength and stability. The hollow basket formed by the skeleton filters water for nutrients as well. The structural elements of the building are connected at different angles on each floor due to its shape. This system allows for an open floor plan, vertical support without interior columns, resistance to winds, and ventilation throughout all floors.

Fig 5: The Gherkin, London, England [3]

5. Milwaukee Art Museum, Wisconsin

The Milwaukee art museum, design in 1975 originally by the architect David Khaler features the Quadracci Pavilion a biomimetic masterpiece of the Architect Santiago carlatrava.. The pavilion is remarkable for its mimicking the span of a birds wings. The pavilion contains the Burke Brise Soleil, which is a movable sunscreen resembling the wings of a bird due to its opening and closing mechanism [1], that opens up for a wingspan of 217 feet (66 m) during the day, folding over the tall, arched structure at night or during inclement weather.

Fig 6: Aerial view of downtown Milwaukee, Wisconsin, focusing on the Milwaukee Art Museum's signature Quadracci Pavilion, designed by Spanish architect Santiago Calatrava, at the Milwaukee Art Museum in Milwaukee, [7]

VII. Conclusion:

The application of the concept of biomimicry goes beyond the desire for better aesthetics, and the need to create an iconic structures which puts the designer in the spot light. Biomimicry is a solution driven approach and is better utilized when issues requiring practical solutions arise. From the modern examples of a biomimicry, we can observe that the design solutions obtained produced less wastage, in terms of energy and materials, in some cases cost, while producing structures which support the eco-system.

Many historic examples of nature inspired architecture will fail the test if compared to modern day examples of biomimicry in architecture, because they lack the features of biomimicry discussed earlier. One may doubt if some of these historic examples (such and the great pyramids of Egypt) were true intentional efforts to replicate nature in a human surrounding. What we do know however, is that they are examples of visual biomimicry and that they have stood the test of time. With this historic examples, we have an understanding that man has always looked to nature as a guiding light to architectural possibilities.

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