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A Study of Biomimetic Architectural traits in a Pre-Medical School Complex in Nigeria: a Case-study of Faculty of Medicine, Kaduna State University (KASU) Complex, Kaduna

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ABSTRACT

Biomimicry is an applied science that derives inspiration for solutions to human problems through the study of natural designs, systems and processes. Nature can teach us about systems, materials, processes, structures and aesthetics (just to name a few). By delving more deeply into how nature solves problems that are experienced today, timely solutions could be extracted and new directions for our built environments could be explored. This research examines Biomimetic design principles in an attempt to identify the traits in the design of the faculty of medicine of Kaduna State University (KASU). Case study methodology was adopted for the research through a descriptive and qualitative analysis. The findings suggested that, knowingly or unknowingly certain biomimetic attributes had been adopted in some aspects of the building design to achieve sustainability in the building. The paper recommends that a holistic approach to design and construction should always be adopted and biomimicy principles should always be considered in the design and planning of academic facilities because it has been shown to support the sustainable agenda.

Keywords: Biomimicry; Faculty of Medicine; Nature; Sustainability; Kaduna

1.0 INTRODUCTION

Biomimetics and biomimicry are both aimed at solving problems by first examining, and then imitating or drawing inspiration from models in nature. Biomimetics is the term used to describe the substances, equipment, mechanisms and systems by which humans imitate natural systems and designs (Yahya, 2006). Panchuk, (2006) defines Biomimicry as an applied science that derives inspiration for solutions to human problems through the study of natural designs, systems and processes. As a result of 3.8 billion years of “research and development” (evolution), nature provides a set of design blueprints that may be used to guide us to create elegant, sustainable, and innovative designs for human technologies (Benyus 1997). Hence, to consciously emulate nature's genius, we need to look at nature differently. In biomimicry, we look at nature as model, measure, and mentor . Nature as model: Biomimicry is a new science that studies nature’s models and then emulates these forms, process, systems, and strategies to solve human problems – sustainably. Nature as measure: Biomimicry uses an ecological standard to judge the sustainability of our innovations. Nature as mentor: Biomimicry is a new way of viewing and valuing nature. It introduces an era based not on what we can extract from the natural world, but what we can learn from it. According Reed (2011) our designs need to be ‘regenerative‘‘, meaning that we need to contribute to biodiversity with our own designs, an approach that not only reverses degeneration of the earth's natural systems, but creates systems that can co-evolve with us, in a way that generates mutual benefits and creates an overall expression of life and resilience. Thus, biomimetic architecture presents a very promising solution to this issue. 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 regenerative built environment (Reed, 2011).

1.1 PROBLEM DEFINITION: AIM/ OBJECTIVES OF STUDY

In Nigeria there is a shortage in electricity supply and a rising cost of fuel due to its scarcity. It is also a known fact that the growth in buildings energy consumption comes predominantly from electricity and has pose a great challenge in the design of educational buildings because of the need to light or condition spaces within the building. Medical school buildings are unique and are known to consist of laboratories, lecture rooms, offices and other ancillary facilities which require energy intensive processes to keep it comfortable for the occupants if not properly designed and planned. Thermal comfort has also been identified as a critical limitation to the articulation of academic interaction; since uncomfortable conditions can lead to lack of concentration, accidents in labs and even adverse ailments. Hence, this paper attempts to look at biomimetic architecture as a solution to the identified problem and also examines the traits in the building design of faculty of medicine, Kaduna Sate

University (KASU) in order to establish how it has addressed the issues of energy efficiency in the faculty complex. Thus, this paper will address the following questions:

i. What are the underlining principles of biomimicry/biomimetic architecture?

ii. How has biomimetic architectural principles addressed energy and thermal comfort issues in the faculty of medicine complex of KASU ?

2.0 LITERATURE REVIEW

2.1 Biomimicry In Perspective

Biomimicry, also referred to in technical terms as Biomimetics was defined by the Biomimicry Institute as a new science that studies nature's best ideas and then imitates these designs and processes to solve human problems. Studying a leaf to invent a better solar cell is an example of this "innovation inspired by nature." Benyus in her book Biomimicry: Innovation Inspired by Nature, 1997 sums it up thus:

1. Nature as Model – Biomimicry is a science that studies nature's models and emulates or takes inspiration from their designs and processes to solve human problems.
2. Nature as Measure – Biomimicry uses an ecological standard to judge the 'rightness' of our innovations. After 3.8 billion years of evolution, nature has learned: What works. What is appropriate. What lasts.
3. Nature as Mentor – Biomimicry is a holistic way of viewing and valuing nature. It introduced an era based not on what we can extract from the natural world, but on what we can learn from it.

It is advocated that Biomimetics goes further than Organic Architecture since it strives to unify the knowledge contained within a diverse field of scientific disciplines into one cohesive unit (Panchuk, 2006). She further states that this approach to design is seen as an integrated network that is dependent upon a feedback system related to the key factors in design; inherent in all of the relevant external and internal forces that influence a design from occupancy, loading, seismic, HVAC to day-lighting inform the direction of the design and interact with one another to create the final solution. The appeal of biomimetics stems not merely from a method for acquiring abstract design ideas from nature but also from the manner in which nature utilizes those ideas (ibid.). Cost is of mutual importance to both natural and man-made environments; the cost of an object, structure, or organism to design, manufacture, construct, maintain and ultimately recycle is significant to life, for many things depend on it. In nature, sustenance is dependent on energy, primary of which is solar energy. Hence, cost is established by energy, where competition for available resources favors the organism that can survive and grow with the least amount of required materials and energy expenditure. Animals must fight for territory, sex, and food while plants develop innovative ways to harness more sunlight than their neighbors; therefore, the organism which survives best is the one that produces more viable offspring per unit of expended energy than its competitors.

2.2 Approaches To Biomimicry

Approaches to biomimicry as a design process typically fall into two categories: Defining a human need or design problem and looking to the ways other organisms or ecosystems solve this, termed here design looking to biology, or identifying a particular characteristic, behavior or function in an organism or ecosystem and translating that into human designs, referred to as biology influencing design (Biomimicry Guild, 2007).

i. Problem-Based Approach

Throughout literature review, this approach was found to have different naming, such as Design looking to biology (Zari,2007), Top-down Approach (Knippers, 2009) and Problem-Driven Biologically Inspired Design (Helms, Vattam and Goel, 2009), all referring to the same meaning. In this approach, designers look up to the living world for solutions and are required to identify problems and biologists then need to match these to organisms that have solved similar issues. This approach is effectively led by designers identifying initial goals and parameters for the design. An example of such an approach is Daimler Chrysler's prototype Bionic Car (plate i). In order to create a large volume, small wheel base car, the design for the car was based on the boxfish (ostracion meleagris), a surprisingly aerodynamic fish given its box like shape.

Plate I: Daimler Crysler bionic cars. (Source: Zari, 2007).

ii. Solution-Based Approach
As stated in the previous approach, this approach was also found to have different naming such as Biology Influencing Design Bottom-Up Approach‖ and Solution-Driven Biologically Inspired Design. When biological knowledge influences human design, the collaborative design process is initially dependant on people having knowledge of relevant biological or ecological research rather than on determined human design problems. A popular example is the scientific analysis of the lotus flower emerging clean from swampy waters, which led to many design innovations as detailed by Baumeister (2007), including Sto‘s Lotusan paint which enables buildings to be self-cleaning.

Plate II: Lotus inspired Lotusan Paint (Source: Zari, 2007).

An advantage of this approach therefore is that biology may influence humans in ways that might be outside a predetermined design problem, resulting in previously unthought-of technologies or systems or even approaches to design solutions (Vincent et al., 2005). The disadvantage from a design point of view of this approach is that biological research must be conducted and then identified as relevant to a design context.

2.3 Biomimicry And Architecture
In the field of architecture, one can see many examples that is influenced or learned from the nature. Constructions like branches of a tree, analogies of flowers, network configurations, etc. inspired the architectural design thinking since the ancient times. This inspiration can be observed in two ways; (1) to reproduce the form with the concern of form finding, (2) or to transfer the process of emergence of a living entity (like material, form, structure, and so on) to design thinking. The first is concern of form finding and most of the time does not refer to a functional and an ecological approach. The second way is a different approach though, which offers to observe and understand the functionality and harmony within the nature. It is important to understand how each living thing has its own functionality to create a nest to survive in its environment, to endure its conditions but performing this with harmony and causing no harm to its environment. These nests are built with instinct, as lightweight, stable, energy efficient dwelling based on a genetic knowledge. Emergence of these natural forms inspired architects and designers to study and research the field of biology and ecology to harness the nature’s way of construction in a global network of harmony, with the objective of creating a sustainable and an ecological built environment. Examples may vary; like the material of a seashell or spider web’s endurance, geometries and spatial relations in a beehive, photosynthesis’ to harness energy from sun, etc. These examples all point out the wisdom behind nature (Alison, Brayer, and Spiller, 2003).

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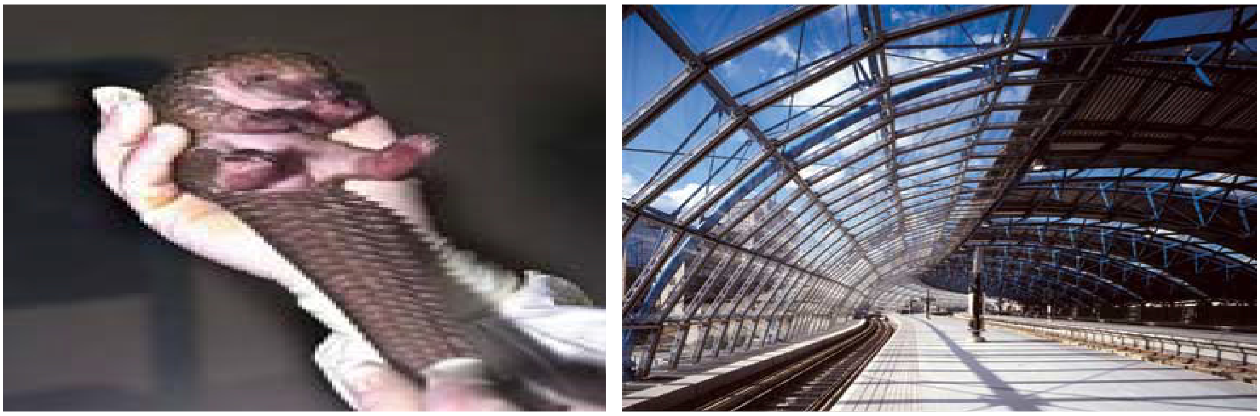

Plate III**:** Nicholas Grimshaw & Partners' Waterlo International Terminal and the pangolin.(Source: biomimicry guild,2007)

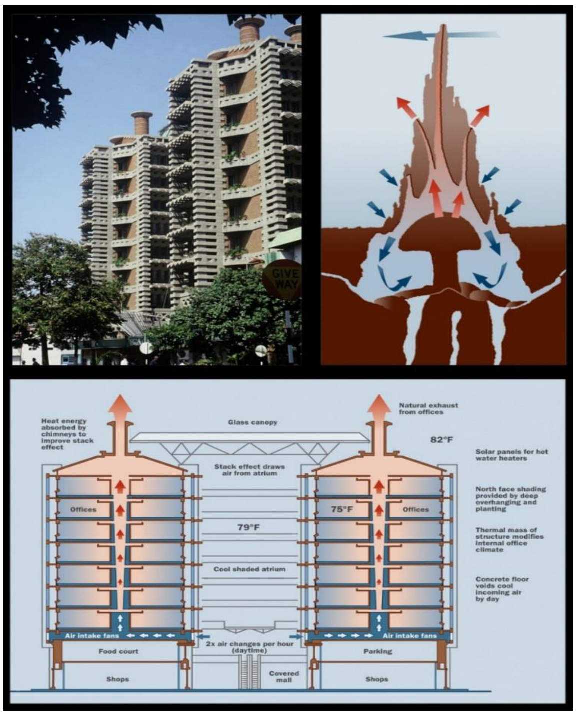

Figure 1. Appication of termite mounds to achieve a natural ventilation in Eastgate Center;(Source: Photograph: © David Brazier. Illustrations by Daniel Gallant/Foundry Zero. Adapted from artwork courtesy of Mick Pearce.)

2.4 Principles Of Biomimicry

The biomimicry principles focus exclusively on nature's attributes; thereby implying that humans have much to learn from the billions of years of the natural world's evolutionary experience. Benyus, (2007) in her book “Inspired by Nature" proposes that a biomimetics approach to architecture design that incorporates an understanding of ecosystems could become a vehicle for creating a built environment that goes beyond simply sustaining current condition to a restorative practice where the built environment becomes a vital component in the integration with and regeneration of natural ecosystems. These can be achieved by adopting nature principles in other words biomimicry principles in architectural designs.

These principles are as follows

1. Nature runs on sunlight
2. Nature need only the energy its need
3. Nature fits form to function
4. Nature recycles everything
5. Nature banks on diversity
6. Nature demands local expertise

7. Nature curbs excesses from within
8. Nature tab the power to limits
9. Nature uses energy for efficiency
10. Nature use waste as a resources
11. Nature uses materials

3.0 RESEARCH METHOD

In this study a qualitative and descriptive research approach will be undertaken in the form of a case study . It is based on evaluation of design schemes that allows incorporation of nature and biomimicry in the design of faculty of medicine KASU in order to achieve energy efficiency. The assessment was carried out through visual surveys, observation, and a checklist on the application of the outlined principles of biomimicry design under study. The principles under study are; use free energy, enhance the biosphere, use minimal energy and materials, and principle of adapt and evolved.

3.1 Limitations

Availability of adequate documented information on faculty of medicine complexes and architecture was a problem since not much research had been conducted on them as compared to that of other health care facilities such as hospitals. Knowledgeable people about the subject matter didn't really provide enough information for the research when interviewed in regards to its architecture.

3.2 Case Study Building : Faculty Of Medicine, KASU.

The Faculty of Medicine is one of the new faculties established in 2008 with the vision to produce medical doctors and other health personnel who are able to understand the normal and abnormal human body, the family and the society; with enough scientific knowledge to undertake further training to become specialists, teachers and researchers. The buildings are organically laid out to avoid the physical challenges of rocks and steep contours of the site. The layout is double and straight forward, with a double entrance into the university from the main road, which further formed branches of access to other functions of the university. The buildings are a conversion of old branch ABU Hospital kaduna which comprises of lecture rooms, laboratories, e-libraries and offices. Most of the earlier buildings are colonial type of buildings, they were designed in simple rectangular-type space allocations laid out in rows as dictated by the contours. The structures from the inside where characterized with long corridor which serve as horinzontal means of escape. Dean's office which is the most imposing structure on site is a bungalow building having its walls finished with stone facing. The dominant building materials found were reinforced concrete, steel, and glass. Construction techniques prevalent on site however, cuts across the time line from colonial type of building to the current trend of building construction. Use of stone, burnt bricks and rammed earth has also been recorded in limited level on site. The source of water for the facility is the main water grid of the Kaduna metropolis and the nearby stream that supplies the nursery unit and most of the gardens. Electricity is via the national grid, with a generator and solar plant as an alternative power source. The size of the facility is limited and with no ample space for expansion. This has evidently been due to the conversion of ABU hospital branch to a university, and the sprouting development of the city, which has therefore rendered room for future expansion for the facility almost impossible.

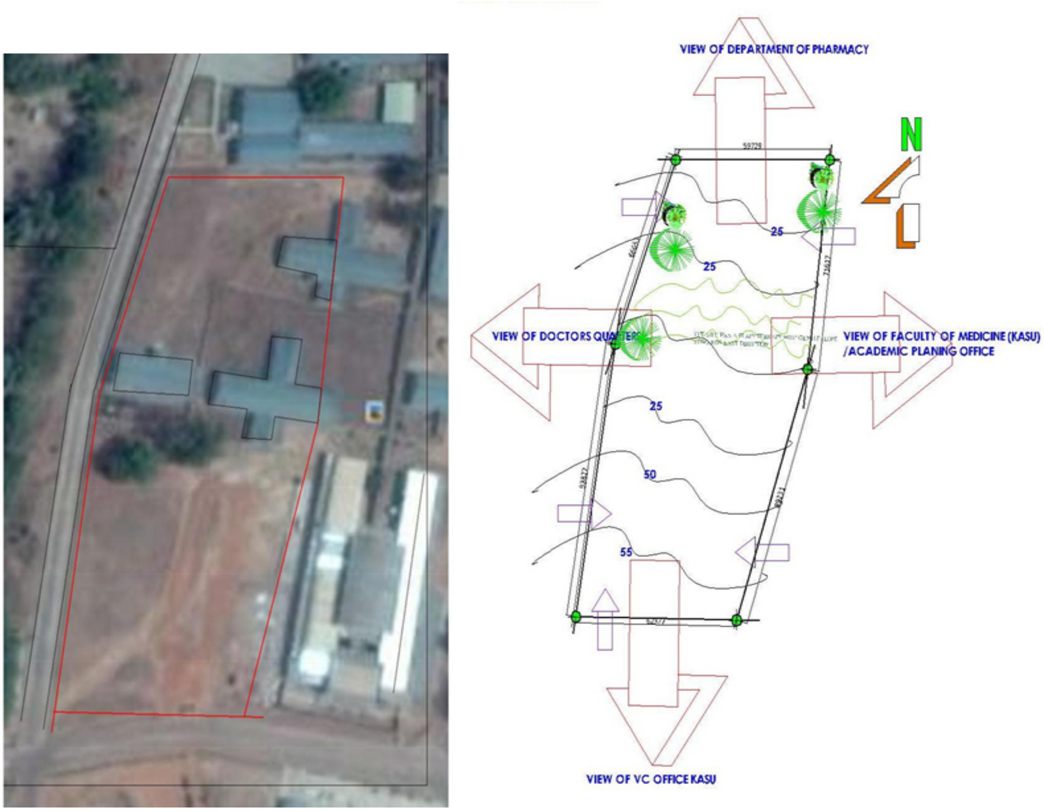

Figure 2: Site view and adjoining structures (Source: Google earth and Authors)

Plate iv: showing façade of faculty of medicine/ Dean's office. (Source: Authors Field work)

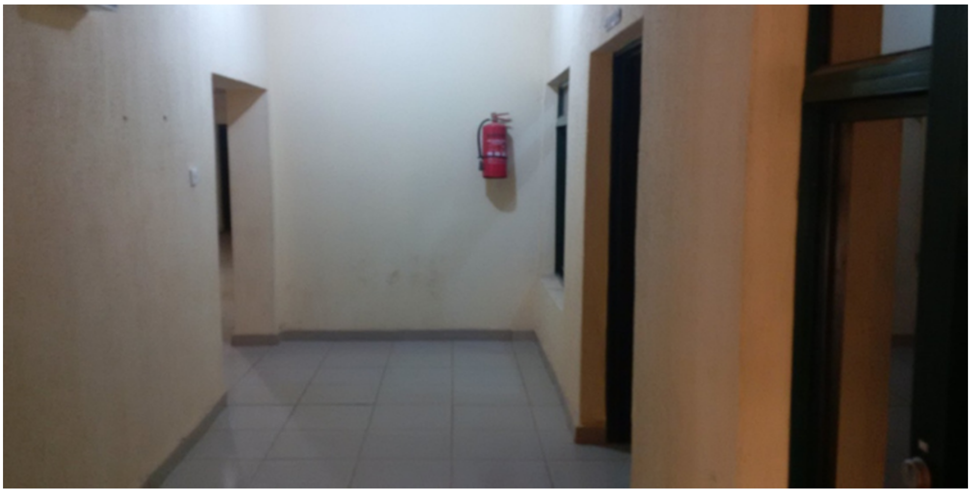

Plate v: Artificial lighting in the Corridor leading to Deans Office. (Source: Authors Field work)

Plate vi. Showing Solar panels used in generating electricity.(Source: Authors Fieldwork)

Table 1: Reflection Of Biomimicry Principles On The Case Study Building

BIOMIMICRY PRINCIPLE 1: USE FREE ENERGY			
Variables	**Features**	**Method of application**	**remark**
Energy/power source	integrated photovoltaic systems	On roof systems	Positive
	- building integrated wind turbines, wind tunnels and shafts.	nil	negative
Energy management methods	-automated operable windows	nil	negative
	-low e-glazing or double pane glazing	nil	negative
	-structural insulated panels and other high performance insulated concrete panels	structural insulated panels on building envelope	Positive
	use of courtyard garden and pool of water to moderate the micro climate	Passive cooling technique, plants.	negative

Source: Authors work

BIOMIMICRY PRINCIPLE 2: ENHANCE THE BIOSPEHRE			
Variables	**Features**	**Method of application**	**Remark**
Source of water	- Water is obtained from the stream -no effort at harvesting, processing and recycling rainwater	source of water is a stream.	Positive
	-use of on-site storm water treatment and ground water recharge	nil	Negative
Working with site topography and native landscape elements	-retention of plants native to location as landscape elements.	most of the native plants were retained	Positive
	- construction of structures to follow the topography of the site	Minimal cut and fill of the site.	Positive
Minimal alteration of natural hydrological systems	-Minimal cover of site with impervious ground cover like asphalt and concrete walk ways to allow for ground water recharge, resticted only to admin area	About 70% of total site area is pervious to rain water.	positive
Water conservation methods	-on-site treatment plants	nil	negative

Source: Authors work

BIOMIMICRY PRINCIPLE 3: USE MINIMAL ENERGY AND MATERIALS			
variables	**Features**	**Method of application**	**remark**
Re-usability of Building materials	-use of recyclable or reusable building materials, such as Thastyron Rastra panels	nil	positive
Use of building materials with high durability	- use of reinforced concrete, aluminium roofing sheets which are of high durability	-use of reinforced concrete, aluminum roofing sheets which are of high durability	Positive
Application of Smart Materials	Control of solar radiation transmitting through the building envelope. Photochromies, Liquid crystals, Suspended particle panels	nil	Negative
	Control of conductive heat transfer through the building envelope. Thermotropics	nil	negative
	Control of interior heat generation, phase change materials	nil	negative
	Secondary energy supply systems and optimization of lighting system	nil	negative

Source: Authors

BIOMIMICRY PRINCIPLE 4: ADAPT AND EVOLVE			
variables	**Features**	**Method of application**	**remark**
Environmental Responsive design	Day lighting, the use of	Use of courtyard	Negative
(features	Skylights. Natural ventilation via stack effect. Sky Gardens.	system and garden The use operable windows and provision of fresh air via sky gardens.	Positive
Regenerative site, design	the use of trees to control micro climate use natural vegetation to control soil erosion	the use of trees to control micro climate	positive
Applying Integrated Cyclic processes & Feedback Loops	- use of water management and waste recycling	-nil	negative

Source: Researcher

Table 2: Case study ratings for reflection of biomimicry principles

S/N	**Biomimicry Principles**	**Ratings**					**Remarks**
		1	**2**	**3**	**4**	**5**	
1	Use Free Energy		✓				Fair
2	Enhance the Biosphere			✓			Good
3	Use Minimal energy and Materials		✓				Fair
4	Adapt and Evolve			✓			Good

Rating Scale= Excellent (5) V.Good (4) Good (3) Fair (2) Poor (1)

Source: Authors

From the above table, it shows that enhancing the biosphere and adapting and evolve had stronger application in the said building with a score of 3 while the use of free energy and minimal energy embodied materials were fair, suggesting the need for more improvement in their applicability.

4.1 Deductions From Case Study

In general the findings made from the case studied can be summarises as follows;
i. The case studied utilises the use of natural lighting and ventilation more than artificial means by providing cross ventilation and enough operable windows.

ii. Most of the materials used in the buildings studied from the building fabric to finishes were modern refined materials (mostly concrete, sandcrete block, aluminium and glass) that require a lot of energy and technology in manufacture and usage instead of using locally sourced materials (low impact materials that are organic in nature).

iii. The case studied looked to alternative energy sources such as solar panels.

iv. The case studied do not have spaces for future expansion, it has a compact site that do not have enough spaces for natural features.

5.0 CONCLUSION

Conclusively, it was found out from the studies that we can seek nature to get solutions to most of our built environment problems. A truly biomimetic approach to architectural design requires an understanding of form, material and structure not as separate elements, but rather as complex interrelations that are embedded in and explored through integral computational design processes. Also from the case study, it showed that the design of the buildings had to some extent had regards for natural solutions towards sustainability but will require a more holistic approach towards achieving it to the fullest.

6.0 RECOMMENDATION

The researcher recommends that nature in the context of its processes, form and materials should be included in the design and planning of our built spaces such as a faculty of medicine complex because of the energy demands. Imitating biological processes has been found to provide solutions to man's built environment problems, and adopting a holistic approach to biomimetic processes in our design will help deal with energy consumption challenges in our designs as has been shown by some the existing example.

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