AN APPLICATION OF BIOMIMICRY SCHEME IN THE DESIGN OF THE FACULTY OF MEDICINE, KADUNA STATE UNIVERSITY (KASU), KADUNA

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AHMADU BELLO UNIVERSITY, ZARIA,

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JANUARY, 2016

DECLARATION

I declare that the work in the thesis entitled **'An Application Of Biomimicry Scheme In The Design Of Faculty Of Medicine, Kaduna State University (KASU), Kaduna,'** has been performed by me in the Department of Architecture under the supervision of Dr. (Arc.) M.M. Mai. The information derived from literatures has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at any university.

_____ _____

ALIYU ISAH SOBA **DATE**

CERTIFICATION

This thesis entitled **'An Application Of Biomimicry Scheme In The Design Of The Faculty Of Medicine, Kaduna State University (KASU), Kaduna , '** by **Aliyu Isah Soba** meets the regulations governing the award of the degree of Master of Science in Architecture in Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

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ALIYU ISAH SOBA

ABSTRACT

The yearnings to achieve energy efficiency, sustainability and economy in design due to global-climatic challenges which affect the environment has called for us to be more innovative in our approach. Various studies have shown that study of natural systems, will trigger innovations in building design and building-product development that are resource efficient, environmentally benign, and aesthetically satisfying". Thus, biomimicry is an applied science that derives inspiration for solutions to human problems through the study of natural designs, systems and processes. This research therefore explores Biomimicry in an attempt to identify a scheme that can be applied to the design of the faculty of medicine for Kaduna State University(KASU) and similar facilities so as to make them more energy efficient and sustainable. A case study methodology was adopted for the research by a descriptive and qualitative analysis of two faculties of medicine within the country (the existing faculty of medicine, KASU inclusive) and three other facilities which reflected biomimetic approach and were all outside the country. The findings suggested that, biomimetic approach to designs have been applied in quite a number of facilities and it has proved to be a sustainable approach to design of buildings. This is because biomimicy principles are tied to features such as natural lighting, natural ventilation, local materials, natural forms, site features, ecological design approach, natural materials and natural processes. It was also found that most of the facilities in Nigeria have no holistic approach to design in regards to sustainability. The thesis 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; Medicine; Nature; Kaduna)

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[CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Education defines the quality of life; it is the foundation on which the society is built. Higher learning takes the intellect to the next level of success and provides a deeper understanding of relevant subjects; it also provides the necessary foundation for economic growth (Famade, Oyimale, Adebola, 2015).This has resulted in the establishment of so many institutions of learning in Nigeria so as to equip the youths to face the challenges ahead. But most of these institutions of learning are faced with energy crisis due to electricity shortage and continuous scarcity and rise in the price of fuel. This has escalated the running cost of academic institutions because they result to active means to maintain a thermally comfortable environment for staff and students. Thus, an academic environmentespecially a pre-clinical medical complex requiressustainable strategies to address the issues of energy efficiency and thermal comfort.Thermal comfort of the academic environment has 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. Mumford, (2006) argues; in some indoor workplaces the temperature and air quality may be less than ideal. Some staff and students may experience discomfort as a result. Hence, mechanical processes have usually be looked upon to avert problems of thermal comfort which have resulted in energy inefficiency which in turn has increased the running cost of academic facilities. Vogel, (1998) argues thus; we do have an alternative technology as a mirror to view our own – the technology of organisms. This approach challenges an unsustainable mechanical - thermal control system and proffers taking inspiration from natural systems and as Panchuk, (2006) suggests; promises to yield new

means by which buildings respond to, and interact with, their users, hence, more subtle and more satisfying methods of thermal control than the present mechanical systems will be created. Vogel, (1998) further states that as systems to compare we could ask for nothing better than nature's designs, for as he insists; nature's technology occurs on the surface of the same planet as that of human culture, so it endures the same physical and chemical limitations and must use the same materials. 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. Biomimicry 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). In view of the aforementioned sustainability solutions that biomimicry presents, this thesis attempts to adopt a biomimic scheme for the faculty of medicine of the Kaduna State University because the large amounts of energy the medical facilities consume on a daily basis in other to power equipment in the laboratories, lighting spaces and conditioning working spaces for improved thermal comfort.

1.2 PROBLEM STATEMENT

The issues of large consumption of energy on a daily basis is among the greatest challenges of large institutions like universities (Oyedepo et.al, 2015). Saleem et.al identifies that thermal comfort plays a major role in the educational sector as it has a big impact on building interior temperature as well as on energy consumption. Thus, in a medical school complex, energy access is a critical enabler of access to medical technologies (World Health Organization, 2014).

In medical schools access to energy is required to power laboratory equipment on a daily basis and maintain a thermally comfortable academic environment as it has 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, in trying to cater for such situations so much is spent on mechanical processes which has high cost implications in the midst of rising cost of energy in Nigeria.

1.3 RESEARCH QUESTIONS

This research intends to answer three basic questions:

i. What are the underlining principles of biomimicry architecture?

ii. What are the core determinants of a medical complex?

iii. How to integrate biomimicry into a medical complex formally and spatially?

1.4AIM/OBJECTIVES OF THE STUDY

1.4.1 AIM

The aim of this research is to explore the principle of biomimicry in the design of faculty of medicine, in an attempt to apply the potentials of both emerging sciences in developing a more sustainable and regenerative architecture.

1.4.2OBJECTIVES

i. To outlinethe basic of biomimicryprinciples in architecture
ii. To identify core determinants of a medical school complex
iii. To integrate the building forms and spatial organization with its immediate environment.

iv. To demonstrate the optimum features of biomimicryin a proposed faculty of medicine complex design.

1.5 SIGNIFICANCE OF STUDY

Due to global-climatic challenges which affect the environment, there are yearnings to achieve energy efficiency, sustainability and economy in design. Hence, as advocated by Benyus, (1997) there is “the need to apply the study of natural systems, which will trigger innovations in building design and building-product development that are resource efficient, environmentally benign, and aesthetically satisfying”. Therefore, solving the problem identified will bring about a new way to solve the challenge of energy consumption; a design that will achieve thermal comfort through passive-natural means.

1.6 SCOPE AND LIMITATION

The scope of this research is limited to the biomimetic approach to problem solving which in this case is energy consumption with emphasis on the natural systems that address the stated problem. The work shall comprise of a critical but concise analysis of a faculty of medicine complex and the concept of designing for thermal comfort.

The limitation encountered during the study includes:

i. Applying certain design decisions could only be contextualized based on scientific theories that answer the various questions as they relate to energy efficiency in the studied systems; proportions, shape, orientation, material.

ii. It is worthy of note as well that any research and on any topic are never conclusive, hence, the time frame for the purpose of this research naturally constitutes a constraint to the research.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter reviews existing literature on the different biomimetic schemes and principles. It gives insight on pre-clinical medical school complex Architecture and recommended design guidelines. It finally recommends the suitable research methods to be employed towards achieving the main aim of the research study.

2.2BIOMIMICRY IN PERSPECTIVE

Biomimicry, also referred to in technical terms as Biomimetics was defined by the Biomimicry Institute thus: (from *bios*, meaning life, and *mimesis*, meaning to imitate) is a new science that studies nature's best ideas and then imitates these designs and processes to solve human problems. 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. Benyus,(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 .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.

2.3 HISTORY OF BIOMIMICRY

The manifestation of the theories and directives of Biomimetics became noticeable in the works of Thompson, (1917)as he sought to illustrate the connection between biological and mechanical forms; it also presents an illustrative inventory of natural forms and the mathematics that define them. Often touted as “the first bio-mathematician” it was Thompson, (1917) who suggested that the influences of physics and mechanics on the development of form and structure in organisms

were underemphasized. He demystified natural forms to a significant level and asserted that no organic forms exist save such are in conformity with physical and mathematical laws. The form of any portion of matter, whether it be living or dead, and the changes of form which are apparent in its movements and in its growth, may in all cases be described as due to the action of force. In short, the form of an object is a 'diagram of forces'." However, while Buckminster Fuller is often attributed with its early incarnations, it is Janine Benyus, a science writer and lecturer on the environment, who is responsible for the recent codification of Biomimicry as a field of research and study. Her 1997 book entitled *Biomimicry:Innovation Inspired by Nature* brought together the recent discoveries in a multitude of disciplines, from engineering to agriculture, which can be traced to research and investigations into the designs and processes found in nature.

2.4 APPROACHES TO BIOMIMICRY

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

2.4.1 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 et.al, 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. The pattern of problem-driven biologically inspired design follows a progression of steps which, in practice, is non-linear and dynamic in the sense that output from later stages frequently influences previous stages, providing iterative feedback and refinement loops (Helms et.al, 2009).An example of such an approach is DaimlerChrysler‘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 *(ostracionmeleagris),* a surprisingly aerodynamic fish given its box like shape. The chassis and structure of the car are also biomimetic, having been designed using a computer modelling method based upon how trees are able to grow in a way that minimises stress concentrations. The resulting structure looks almost skeletal, as material is allocated only to the places where it is most needed. (Vincent et al, 2006).



Plate I**:**DaimlerCrysler bionic cars.
(Source: Zari, 2007).

The possible implications of architectural design where biological analogues are matched with human identified design problems are that the fundamental approach to solving aThe *Bionic Car* illustrates the point. It is more efficient in terms of fuel use because the body is more aerodynamic due to the mimicking of the box fish. It is also more material efficient due to the mimicking of tree growth patterns to identify the minimum amount of material need in the

structure of the car. The car itself is however not a new approach to transport. Instead, small improvements have been made to existing technology without a re-examination of the idea of the car itself as an answer to personal transport (Zari,2007). Designers are able to research potential biomimetic solutions without an in depth scientific understanding or even collaboration with a biologist or ecologist if they are able to observe organisms or ecosystems or are able to access available biological research. With a limited scientific understanding however, translation of such biological knowledge to a human design setting has the potential to remain at a shallow level. It is for example easy to mimic forms and certain mechanical aspects of organisms but difficult to mimic other aspects such as chemical processes without scientific collaboration (Zari,2007).Despite these disadvantages, such an approach might be a way to begin transitioning the built environment from an unsustainable to efficient to effective paradigm (McDonough and Braugart, 2002).

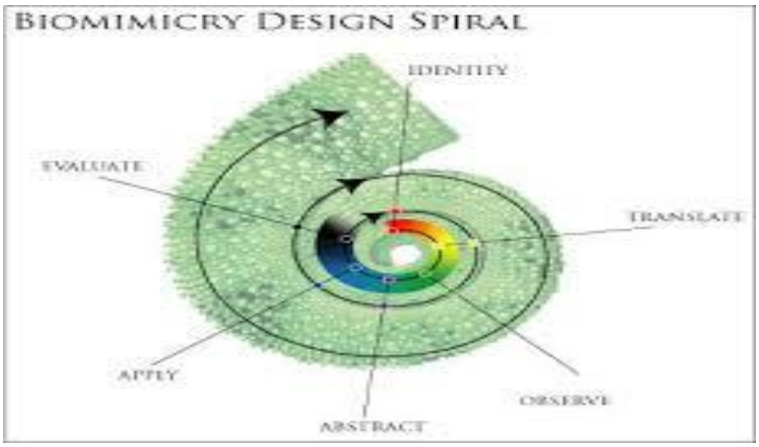


Fig2.1:Biology Design Spiral.

(Source:Biomimicry Institute2007)

The Biomimicry Institute has referred to this design approach and explained it through the Challenge to Biology Design Spirals.

2.4.2 Solution-Based Approach

As stated in the previous section, this approach was also found to have different names 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. The potential for true shifts in the way humans design and what is focused on as a solution to a problem, exists with such an approach to biomimetic design (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. Biologists and ecologists must therefore be able to recognize the potential of their research in the creation of novel applications.

2.5 BIOMIMICRY AND ARCHITECTURE

In the field of architecture, one can see many examples that is influenced/ 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 just a 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). Biomimicry inspires architecture in different levels as biology does in the nature and these levels can be summarized under three categories: (1) form, (2) process, (3) ecosystem. Form and processes can mimicked in an ecosystem. Benyus, (1997) explains these levels with the example of an owl's feather. Feather can be replicated by its formal attributes but this will not lead to an ecological and a sustainable solution. This is similar to biomorphic approach but

the distinction between them is the process. If the process is mimicked it is possible to achieve the properties of the feather; how it is produced without using toxic waste or high energy consumption and how it affects the body heat and energy conservation. The third level is the ecosystem level, explaining how the bird and the feather exists together in a larger biosphere with other organisms. This approach is methodized by Zari(2007) to apply to a design or an architectural problem. The three levels mentioned above are rearranged and seperated into sublevels (See Table 2.1) and explained how biomimicry is considered for a design problem.

Table 2.1A Framework for the Application of Biomimicry (Zari, 2007)

Level of Biomimicry		*Example - A building that mimics termites:*
Organism level (Mimicry of a specific organism)	*form*	The building looks like a termite.
	material	The building is made from the same material as a termite; a material that mimics termite exoskeleton / skin for example.
	construction	The building is made in the same way as a termite; it goes through various growth cycles for example.
	process	The building works in the same way as an individual termite; it produces hydrogen efficiently through meta-genomics for example.
	function	The building functions like a termite in a larger context; it recycles cellulose waste and creates soil for example.
Behaviour level (Mimicry of how an organism behaves or relates to its larger context)	*form*	The building looks like it was made by a termite; a replica of a termite mound for example.
	material	The building is made from the same materials that a termite builds with; using digested fine soil as the primary material for example.
	construction	The building is made in the same way that a termite would build in; piling earth in certain places at certain times for example.
	process	The building works in the same way as a termite mound would; by careful orientation, shape, materials selection and natural ventilation for example, or it mimics how termites work together.
	function	The building functions in the same way that it would if made by termites; internal conditions are regulated to be optimal and thermally stable for example (fig. 6). It may also function in the same way that a termite mound does in a larger context.
Ecosystem level (Mimicry of an ecosystem)	*form*	The building looks like an ecosystem (a termite would live in).
	material	The building is made from the same kind of materials that (a termite) ecosystem is made of; it uses naturally occurring common compounds, and water as the primary chemical medium for example.
	construction	The building is assembled in the same way as a (termite) ecosystem; principles of succession and increasing complexity over time are used for example.
	process	The building works in the same way as a (termite) ecosystem; it captures and converts energy from the sun, and stores water for example.
	function	The building is able to function in the same way that a (termite) ecosystem would and forms part of a complex system by utilising the relationships between processes; it is able to participate in the hydrological, carbon, nitrogen cycles etc in a similar way to an ecosystem for example.

1. Organism Level

In this level, solutions related to efficient energy usage and materials which are established already. In brief, it is mimicking an organism's physical attributes. An example at this level, based on mimicry of form and process is Waterloo International Terminal (See Plate III) design by Nicolas Grimshaw& Partners. Considering its high span, the terminal need to respond to

dramatic pressure changes as the train arrival and departure. Because of that glass panels are arranged like the scale of a pangolin, to adapt the imposed air pressure (Zari, 2007). Replicating an organism level is related to specific features to solve a certain specific problem thus biomimicry is not integral idea of a design and design may remain conventional. The design may result with a new, fancy looking building but ecological outcome is not necessary at this level.

2. Behaviour Level

Mimicking in a behaviour level can be achieved to explore and understand how an organism relates and behaves in its own environment. It is possible to understand this level with observing how an organism tend to operate in its environmental capacity and within limits of energy and material availability. (Zari, 2007) Termites are the most common example to explain this level. As seen in Table 1, in behaviour level termites build their nests to protect and stabilize the heat of the fungus combs at 30 degrees Celsius despite the 21 degrees range in temperature, where they store the fungi they produce. Because of that termites build a 13cm tall ventilation channel which ventilates the hot air outside and cold air inside (See Figure 2.2) The Eastgate Shopping and Office Center in Zimbabwe uses the same behaviour to naturally heat and cool the building to make it more energy efficient. Behaviour level mimicry can not be suitable for all situtations and context should be taken into consideration. A suitable behaviour for a living organism may not be suitable for all the time.

3. Ecosystem Level

This level of biomimicry intends to create a whole ecosystem which incorporates the other two





levels to achieve a sustainable environments. This means a deep comprehension of ecology and the regenerative processes of the nature. This level may begin from a small scale and tends to lead to a bigger scale of thinking like green cities or eco-cities.

Plate III**:**Nicholas Grimshaw& Partners' Waterlo International Terminal and the pangolin.

Source: grimshaw-architects.com

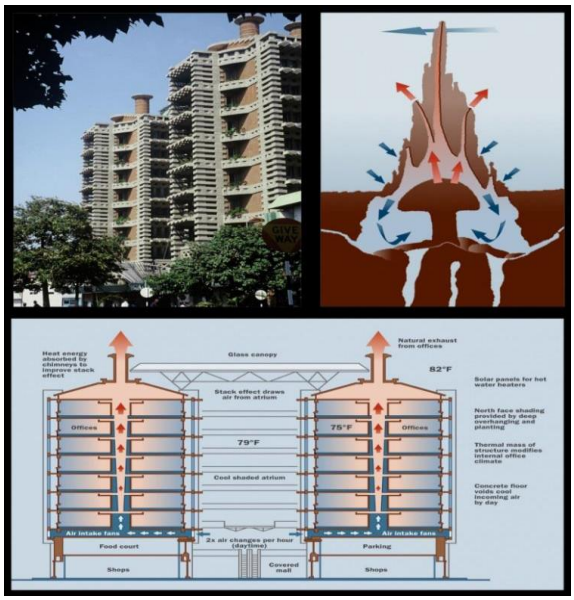


Figure 2.2. Application of termite mounds to achieve a natural ventilation in Eastgate Center;

Source: www.inhabitat.com/eastgate center

2.6BIOMIMETIC MODELS

Basically there are three models which the designer should consider when applying the principles of biomimicry.

i. Nature as Model

Biomimicry is a science that studies nature's models and then imitates or takes inspiration from these designs and processes to solve human problems, example, and solar cell inspired by a leaf and birds flight methods for high speed train.

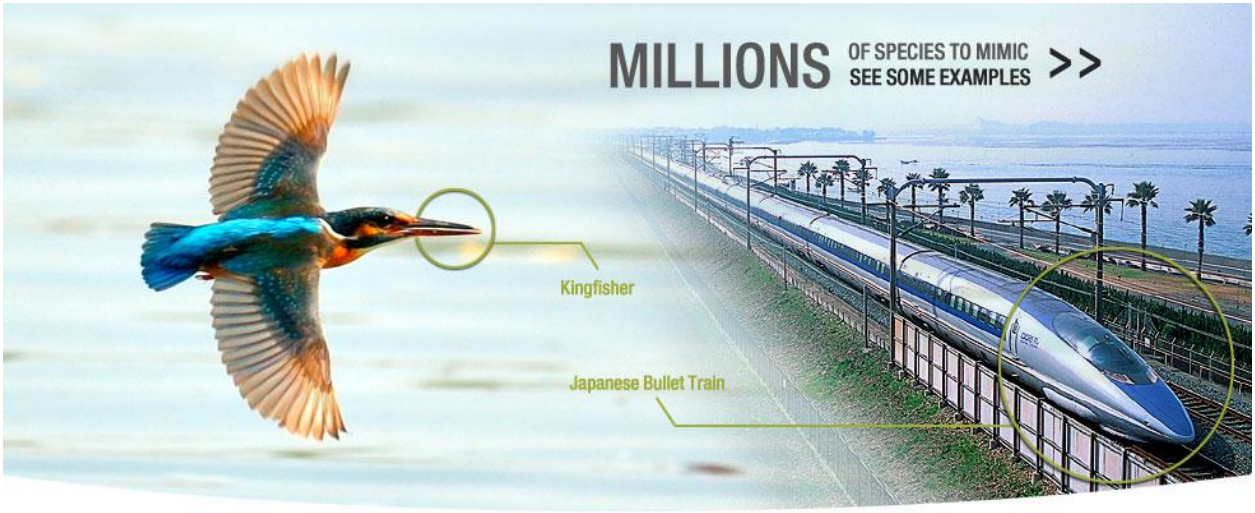


Fig2.3:Showing BiomimcryAs a Model

Source:Biomimicry Institute,(2012)

ii**Nature as Mentor**

Biomimicry uses an ecological standard to judge the righteness of our action. After 3.8 billion of years of evolution, nature has learned: What works? What is appropriate? What lasts?

iii. Nature as Measure

Biomimicry is a way of viewing and valuing nature. It introduces an area based on what we can extract from the natural world, but on what we learn from it (Benyus,1997).

2.7PRINCIPLES 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, (1997) in her book “Inspired by Nature" proposes that a biomimetic

approach to architecture design that incorporates an understanding of ecosystems is paramount. She went further by saying it 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 biomimetics principles in architectural designs.

These principles are as follows

1. Nature runs on sunlight
2. Nature uses only the energy it needs
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 tabs the power to limits
9. Nature uses energy for efficiency
10. Nature uses waste as a resource
11. `Nature uses materials

2.8 BIOMIMICRY AND SUSTAINABILITY

Biomimicry involves learning from and emulating biological forms, processes, andecosystems tested by the environment and refined through evolution (Benyus, 2013). Biomimicry canbe

applied to solve technical and social challenges of any scale (Benyus, 1997).Biology has inspireddesign since prehistoric man fashioned spears from the teeth of animals and mimickedthe effective sneak-and-pounce hunting technique of large predators, but thedevelopment of a methodological framework for translating biological strategies intodesign innovations is a recent one. Various forms of biomimicry or bio-inspired design are discussed by researchers and professionals in the field of sustainable architecture (Reed, 2006, Berkebile, 2007), the widespread and practical application of biomimicry as an architectural design method remains largely unrealized, as demonstrated by the small number of built case studies (Faludi, 2005).The popularization of biomimicry is exciting not just because of its economic prospects, but because of itstremendous potential to inspire eco-friendly designs at this critical juncture in humanhistory (Kennedy et al, 2015). Biomimicry forces a new set of questions that can be applied to the designprocess as well as the outcome. Biological designs are, for instance, resilient,adaptable, multifunctional, regenerative, and generally zero-waste. When deeplyinformed by biology, design thinking shifts away from an anthropocentric model andconsiders product life cycles and earth system limitations.This points to the fact that biomimetic design approach leads to sustainable solutions.

2.8.1Biomimicry and Environmental Design

Biomimicry is a science that studies nature's models and then imitates or takes inspiration from these designs and processes to solve human problems. Biomimicrygained the attention of environmental designers after it was identified as one of the most important principles of sustainability on Mclennan and Berkebille's "The Philosophy of Sustainability Design: the Future of Architecture" (2004, p.43). Since this publication, Benyushas recognized that 'the built environment is the most fertile ground for biomimicry (Livingston, 2008).Environmental design

is defined as the design of the physical worlds happed and constructed by humans at a scale, whether city, building or interior (Klein, 2009).Environmental design describes any effort to integrate the artificial built environment with the surrounding natural world in a manner that preserves limited resources. In more recent times, environmental design has taken on a new urgency. The rising cost and scarcity of fossil fuels like oil have encouraged sustainable development practices that employ techniques to reduce energy consumption and utilize renewable sources of energy for their functioning (Regenerative Leadership Institute,2015)Therefore, a deeper connection among people, nature and the built environment will be sufficient to achieving long term goal of a sustainable, healthy and well-functioning society.

2.9 DESIGN CONSIDERATIONS OF A FACULTY OF MEDICINE COMPLEX

The exacting demands of medical education are always evolving, driven by relentless advancements in medical knowledge, technology, and patient care. Thus, medical school architecture must also evolve and be flexible, to house new curriculums informed by state-of-the-art medical treatment (Kelsey,2010). Medical schools require architecture to improve not only the academic, but also the social experience, in part to boost student retention rates. This requirement translates into spaces for spontaneous, informal social and academic interaction. Some medical school requirements are enduring. School administrators, staff, and students want architecture that reflects the pride and prestige of the institution. In addition, today's new structures need to adhere to emerging green standards of resource conservation. Thus, according to Kelsey (2010), the following design parameters should be put into consideration;

1. Interdisplinary Approach

That being the new reality, medical school architecture and design must accommodate a circular loop of information and feedback, rather than a linear curriculum of sequential stages. Spaces designed for interdisciplinary approaches, much like collaborative research facilities, must encourage human interaction. Medical schools today are reviewing their facilities to determine how, perhaps unintentionally, they work against informal collegiality. Simple factors, such as circulation patterns and proximity of spaces, can encourage or discourage interaction among groups of students, professors, and guests. Designing the facility to put people into places where they come into contact with others social spaces enlarged stairway landings, and open corridors encourages chance meetings as well as organized interactions. This begins to shift the education culture informally, easing the transition to a more collaborative pedagogical structure.

Mirroring real-world clinical environments is another means to encouraging interaction, by placing students into clinical treatment scenarios where they are required to develop a team-based approach to care. Spaces that mimic an emergency or operating room setting impart a sense of place and complement the sophisticated full-body simulation mannequins that are central to the hands-on training conducted in such facilities. Not only emergency and operating rooms are changing, but patients rooms as well. Acuity-adaptable approaches to treatment, now seen in more hospitals, require teams of specialists, accompanying technology, and changing levels of care to come to the patient's own environment, that of the patient room. The old model—shuttling the patient around the hospital—is becoming outmoded, thus dictating changes in medical school architecture and instruction as well. These complex spaces require a variety of support spaces, such as control rooms, debriefing areas, observation suites, part-task rooms, and storage and equipment. Placing these new spaces near more-traditional lecture halls, labs, and

classrooms plays a key role in encouraging interaction among students and faculty, while creating efficient learning environments attuned to the changing realities of modern hospitals.

2. Flexibility

Today's student more-easily works in small-group settings, can focus well in distracting surroundings, and is adept at using technology. This means that traditional pedagogies, such as gross anatomy labs, can be augmented with new technologies, such as computer and internet access at every station. The technology-rich, smaller-scale classrooms of today are a constant reminder that architectural flexibility is the key element in programming and design to extend the life and usefulness of a new facility. Large open spaces, sturdy floor loads, and high ceilings allow floor layouts and technology to be altered as needed.

2.10CONTEXT AND APPLICATION OF PRICIPLES OF BIOMIMICRY IN THE FACULTY OF MEDICINE COMPLEX

Nature can teach us about materials, processes, structures and aesthetics . By delving deeply into how nature solves problems that we experience today, we can extract timely solutions and find new directions for our built environments. Architects can benefit from biomimicry to make buildings better by pushing for more natural, integrated, efficient and healthy solutions. There is a need to take a look at the role aesthetics plays in nature - with the way they function and form so synergistically merge. Perhaps this is a way for buildings to harmonize with nature in renewed ways - making built environments more environmentally sound and healthy for occupants. Thus, the context of biomimetic design approach in medical schools complexes is as follows:

1. As identified by Oyedepo et al, (2015) academic institutional buildings consume large amounts of energy on a daily basis and so there is a need for the buildings to be regenerative and highly efficient in energy, water and form. Nature is believed to resolve this triple requirement of energy, water and form.
2. W.H.O, (2014) asserts that energy access is a critical enabler of access to medical technologies. Thus, the architectural design of faculty of medicine complex increasingly seeks to incorporate concepts and techniques, such as the use of minimal energy and material, power supply e.g Anatomy laboratory form and process optimization that have parallels in nature
3. Architecture and biology share a common language because both attempt to model adaptation in the environment, finding solutions that work and demanding local expertise.
4. The modern design of a medical complex involves enhancing the Biosphere. Reducing the impacts in buildings on the environment and human health (Kesley,2010). Nature uses and builds with life friendly materials and processes. Nature recycles everything.

2.11DEDUCTIONS

The chapter examined biomimetics, and its relationship to architecture and the design of a pre-clinical medical school complex. It went further to study biomimicry approaches in architecture and its application in creating a sustainable medical school complex. It was found that looking to nature or biological processes provides answers man's built environment challenges in a sustainable manner. The study also found out that adoption of biomimicry in architecture can be translated in three levels which are; the organism ;behavioural and at the ecosystem level. Thus,

the chapter prepares the stage for the examination and presentation of existing cases related to the study above with the view of assessing what has been done and how it can be applied in the proposed Faculty of Medicine, Kaduna State University. Therefore a qualitative and descriptive research approach has been adopted and chapter three describes the research Methods.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 INTRODUCTION

In order to find and develop a way forward for creating a sustainable design for a pre- clinical faculty of medicine complex in Nigeria; there is a greater need to draw together and evaluate a number of medical school settings especially those with biomimicrydesign attributes to better inform the design, the recommendations as well as further research.

3.2 RESEARCH DESIGN

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 design of academic environments especially a medical school complex 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 (McLennan, 2004).

3.3 DATA COLLECTION

Case studies in Architecture begin with a documentation of the physical characteristics of the case, and for theoretical research they may require the use of general methods of data collection . However, the method of data collection adopted for this study is observations, visual survey, and checklist of the level of application of Biomimicrydesign on the cases studied.

3.3.1 Instrumentsof Data Collection

The instruments of data collection used are listed below.

1. Photographs

Photographs were taken of relevant case studies to ascertain the features of bio mimicry in architecture as well as the extent, to which they were applied, that is to say, if their extent of application was strong, weak or non- existent.

2.Interview schedule

Staff from anatomy department A. B. U Zaria and Dean Faculty of medicine Kaduna State Universitywere interviewed to get more information on some of the medical school complexes.

3. Sketches

Sketches were made of some parts of the selected case studies. These sketches showed the spatial organisation of some of the case studies.

4. Notes

These notes where in form of field forms outlining the variables for biomimicry design and the character of a faculty of medicine complex.It presents a checklist of the level of application of these principles.

5. Related Literature

The observations and data collected from the interviews, and case studies were crosschecked from relevant literatures in order to make sure that the right information was documented. Some

of the literatures used for this research focused on the principles of biomimicryand design medical school complexes.

3.4 PROCEDURES FOR DATA COLLECTION

The procedure for data collection involved visits to three local case studies and taking a visual analysis of their architectural planning and features. These buildings were then evaluated on the created field forms.

However, the foreign case studies were gotten through the internet and their features evaluated on the field forms as well.

3.5 CRITERIA FOR SELECTION OF CASE STUDIES

The cases were purposively selected .This suggested that a case is identified for study due to its inherent qualities which were in relation to the phenomenon under investigation. The case studies selected for this study were sampled purposely on two bases.

i. A faculty of medicine with adequate coverage in scope of facilities required to operate as an anatomy department.
ii. A facility that possesses some bio-mimetics design features.

3.6 CASE STUDIES ASSESSMENT CRITERIA

According to data collected from the building technical manual, (1996); the U.S Department of Energy (DOE), 2010; and Ruys, 1990; it can be deduced that the basic criteria for assessment of research facility on issues related to biomimicry are;

i. Site planning and landscaping

ii. Spatial organization and design

iii. Structural and dominant building materials

iv. Energy sources and resources

v. Access to basic amenities and services

vi. Size and future expansion

vii. Aesthetics and expression

On the level of reflection of bio-mimetic Design principle, a checklist was employed to ascertain the magnitude of reflection for each principle. Below in 3.6.1, shows a sample of checklist method applied on each of the case studies. It shows the result of observations made on each element as against its reflection on each outlined principle. It should however be noted that the principle of holistic approach to design is excluded from this exercise. This is because it is the least tangible of all the principle, and only deals with expressions of the way thoughts, interaction, design processes, and construction are carried out as a process(McLennan, 2004).

3.6.1 Assessment Of Application Of Principle Of Biomimicry

1.Principle 1: Use of Free Energy

Life learnt to harvest energy from the sun and to transform it for work without creating toxic by-products. This principle supports the use of available energy sources that do not degrade the environment from the point of generation up to the point of consumption by the final consumer and are renewable over time thus not posing as a risk to future generation in terms of exhaustion or ecological degradation (Baldinger, 2006).

2.Principle 2: Enhancing the Biosphere

Natural filtration environment filters out and absorbs components that would otherwise pollute the local ecosystem. This principle stipulates the preservation of the existing natural water cycle and site design and building improvements such that they closely emulate the site's natural "pre development hydrological systems. The emphasis is on retention of storm water and on-site filtration and ground water recharge using methods that closely emulate natural systems as well minimization of unnecessary and inefficient use of potable water on the site while maximizing the recycling and re-use of water, including harvested rainwater, storm water and grey water (governor's green government council, 2007).

3. Principle 3: Use minimal Energy and Materials

Nature always tries to use energy and materials efficiently, successfully minimizing mass and energy use. This principle encourages the minimal use of non-renewable construction materials and other resources that are not recyclable. Consequently, it allows for the use of only recycled content materials, modern resources efficient engineered materials such as polystyrene and other composite type structural system wherever possible (governor's green government council, 2007). These materials are to be designed such that effectively provide for thermal efficient so as to achieve thermal comfort for the users of the building.

4. Principle 4: Adapt and Evolve

This looks at the regenerative tendencies of nature. It ability to respond to the environment by the use of trees, shrubs, and hedges to enhance the micro climate and also to control soil erosion.It also looks at design systems such as skylights, courtyards and the employment of stack strategies to improve air quality within the building envelope.

3.7 Data Analysis And Presentation

Analysis will be based on the data collected from the visual survey and observation is based on the descriptive accounts as observed, and noted via the instruments of data collection . Brief introduction, account of independent variables, and checklist on the application of Biomimicry design principles were used to capture a better perspective of the facilities for more effective evaluation. Instruments used in data presentation were photographs, figures, and tables, for more explicit illustration.

3.7.1. Photographs

Pictures of the existing faculty of medicine complexes studied were taken and documented showing the facilities and how they have reflected biomimetic design principles in the design and planning of the facility as well as the degree of its application. Refer to plates under case studies (chapter four).

3.7.2 Tables

The data collected in this research are documented and presented based on the biomimicry design principles as case study assessment tables. Refer to tables under case studies (chapter four).

3.7.3. Figures

The data collected in the case studies are also documented in form of drawings, such as the building's plans. Refer to figures under case studies (chapter four).

3.8Limitations

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. Searching for pertinent information from the internet was not easy since most of the web sites did not provide free research information to the general public and this also made the gathering of information more difficult.

3.9 CONCLUSION

Now that the research methodology in the form of a research design, data collection methods, measuring instruments, sampling and data analysis has been discussed, the stage has been set for implementation of data collection and analysis process. Therefore the next chapter will deal with the presentation and analysis of the results.

CHAPTER FOUR

DATA ANALYSIS AND FINDINGS

4.1 Introduction

This chapter presents the case studies buildings location and followed by the observations on the medical school architecture and biomimicrydesign principles. The building descriptions are based mainly on the published literature of one kind or another, physical observations and conversations with building operators and occupants during the visit. Some photographs captured during the field work are also presented. Certain building diagrams that show the building form, section or elevation as well as the layout were customized to fit this presentation.

4.2 CASE STUDY 1: FACULTY OF MEDICINE PRE-CLINICAL KADUNA STATE UNIVERSITY (KASU) KADUNA STATE

4.2.1 Introduction

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.

4.2.2 Location

The university main campus is located along TafawaBalewaWay, Anguwan. Rimi Kaduna North Local Government, Kaduna State.

4.2.3Facilities: The building is a conversion of old branch AhmaduBello University Hospital Kaduna which comprises of lecture rooms, laboratories, e-libraries and offices.

4.2.4 Brief Description of Design

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'soffice which is the most imposing structure on site is a bungalow building having its walls finished with stone facing.



Plate iv: showing stone finish façade of faculty of medicine/ Dean's office. (Source: Field study, 2015)

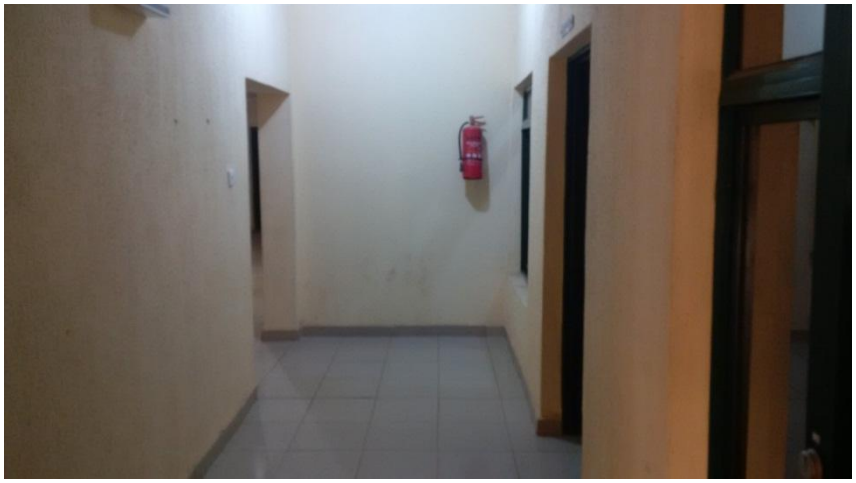


Plate v: Showing the need for artificial lighting of the corridor leading to Deans Office. (Source: Field Survey, 2015)

i. Dominant Building Materials

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 inlimited level on site.



Plate vi: Showing Department of Physiology. (Source: Field Study, 2015)

ii.Site Planning and Landscaping

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, witha double entrance into the university from the main road, which further formed branches of access to other functions of the university.

iii.Energy Sources and Resources

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



Plate vii: Showing solar panels as source of electricity. (Source: Field Study, 2015)

iv. Size and Future Expansion

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 forthe facility almost impossible.

v. Reflection of Bio mimetic Design Principles on the Architectural Elements

The study carried out on the facility based on the guiding design principles of bio mimicry in the research facility is as expressed in tables4.1-4.4 below.

Table 4.1 Assessment of application of Biomimicry Principle one at Kaduna State University (KASU).

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: Researcher

Table 4.2 Assessment of application of Biomimicry Principle Two at Kaduna State University (KASU).

BIOMIMICRY PRINCIPLE 2: ENHANCING 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: Researcher

Table 4.3Assessment of application of Biomimiciy Principle Three in Kaduna state university KASU

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 ThastyronRastra 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: Researcher

Table 4.4 Assessment of application of Biomimicry Principle four in Kaduna State university KASU.

BIOMIMICRY PRINCIPLE 4: ADAPT AND EVOLVE			
variables	**Features**	**Method of application**	**remark**
Environmental Responsive design	Day lighting, the use of	Use of courtyard	positive
(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





Plateviii**:** showing façade of AnatomydepartmentPlate ix:Anatomy departments showingvehichle(Source: Author's Field work, 2015).

4.2.5. Deductions

From the appraisal of this case, it shows that there is a mixture of readily available building materials of granite stone finish and modernly produced materials are quite energy intensive in terms of their production. This case also shows that the site planning and landscaping considered the terrain of the environment. From tables 4.1-4.4, it shows that alternative power sources were considered to complement the electrically generated power but much was not considered in the design and planning of the facility.Most of the circulation spaces needed to be lighting and ventilated through artificially means.

4.3 CASE STUDY TWO: FACULTY OF MEDICINE PRE-CLINICALS, AHMADU BELLO UNIVERSITY ABU, ZARIA.

4.3.1 Location

The faculty is located in the university main campus samara, along usmandanfodio hotel – Area BZ route.

4.3.2 Facilities: The building consists of different departments related to medicine and the facilities comprises of lecture rooms, laboratories, e-libraries and offices.

4.3.3. Brief Description of Design.

i. **Spatial Organization and Design**

Most of the earlier buildings are colonial type of buildings; they were designed in simple rectangular-type space allocations laid out in rows. The admin building is at of the center between anatomy department and physiology department, structures which are of colonial origin with new trends of design.

ii. Structure and Dominant Building Materials

The dominant building materials found were reinforced concrete, steel, and glass. Different types of screening and glazing systems have been used on the buildings. Materials involved

in the screening include, concrete screened walls for lighting and ventilation on the main building.

iii. Energy Sources and Resources

The source of water for the facility is the main water grid of the Kaduna metropolis. Electricity is via the national grid, with a generator plant as an alternative power source.

vi. Aesthetics and Expression

On the issue of aesthetics and expression, the buildings reflect both colonial and modernist style of architecture with some elements of application of indigenous use of style and materials on the facility.

v. Reflection of Bio mimetic Design Principles on the Architectural Elements.

The study carried out on the facility based on the guiding design principles of attaining sustainability in research facility is as expressed in table 4.5-4.8 below.

Table 4.5 Assessment of the application of Biomimicry principle one in Faculty of medicine pre-clinicals (ABU).

BIOMIMICRY PRINCIPLE 1: USE FREE ENERGY			
variables	**Features**	**Method of application**	**remark**
Energy/power source	integrated photovoltaic facade systems	Nil	negative
	- 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.	Positive

Source: Researcher

Table 4.6 Assessment of the application of Biomimicry principle two in Faculty of medicine pre-clinicals (ABU).

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.	Nil	negative
	-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, restricted 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: Researcher

Table 4.7 Assessment of application of BioinimicryPrinciple threein Faculty of medicine pre-clinicals (ABU).

BIOMEMICRY 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 ThastyronRastra panels	nil	negative
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	

	Secondary energy supply systems and optimization of lighting system	nil	negative

Source: Researcher

Table 4.8 Assessment of application of Biomimicry Principle Four in Principle threein Faculty of medicine pre-clinicals (ABU).

BIOMIMICRY PRINCIPLE 4: ADAPT AND EVOLVE			
variables	**Features**	**Method of application**	**remark**
Environmental Responsive design features	Day lighting, the use of Skylights.	Use of courtyard system and garden	positive
	Natural ventilation via stackeffect.	The use operable windows and	Positive
	Sky Gardens.	provision of fresh air via sky gardens.	
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



Plate x: ABU Faculty of Medicine

Source; Field Work



Plate xi: ABU. Side view

Source; Field Work

4.3.4 Deductions

This case shows that much of the building construction technique and materials has high embodied energy in it when related to the cost of production. The complex also has no alternative energy source. From its design and planning, natural lighting and ventilation was maximized by the use of courtyard systems. See tables 4.5-4.7.

4.4 CASE STUDY THREE -EAST-GATE BUILDING, HARARE,ZIMBABWE.

4.4.1 Brief Introduction

Commissioned in 1996, The East gate Centre is a shopping center and office block in central Harare, Zimbabwe. Designed to be ventilated and cooled by entirely natural means, it was probably the first building in the world to use natural cooling to this level of sophistication.

The East gate Centre in Harare, Zimbabwe, typifies the best of green architecture and ecologically sensitive adaptation. The country's largest office and shopping complex is an architectural marvel in its use of bio mimicry principles. The mid-rise building, has no conventional air-conditioning or heating, yet stays regulated year round with dramatically less energy consumption using design methods inspired by indigenous Zimbabwean masonry and the self-cooling mounds of African termites.

Designed by Architect Mick Pearce in conjunction with engineers at Arup Associates,The East-gate Centre's design is a deliberate move away from the "big glass block". Glass office blocks are typically expensive to 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 keepthe expensively conditioned atmosphere inside, leading to high levels of air pollution in the building. Artificial air-conditioning systems are high-maintenance, and Zimbabwe has the additional problem that the original system and most spare parts have to be imported, squandering foreign exchange reserves.





Plate xii: showing exterior of building

building(Source: www.inhabitat.com/eastgate center)

Plate xiii**:** showing interior of

(Source:www.Inhabitat.com/eastgatecenter)

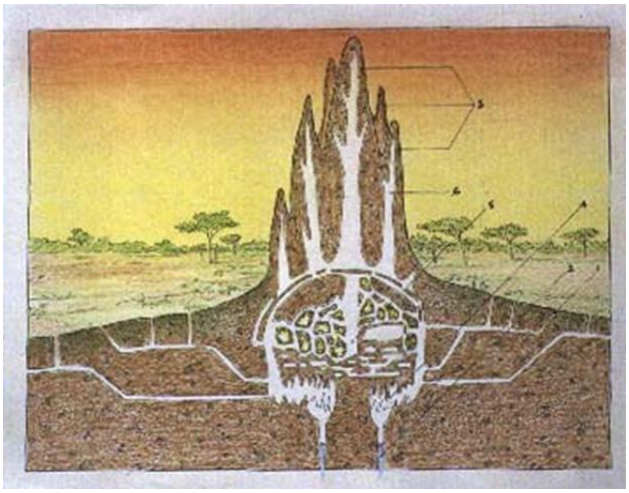


Figure 4.1: Thermal control process in the termite mould employed in the building

Source:www.inhabitat.com/eastgate center

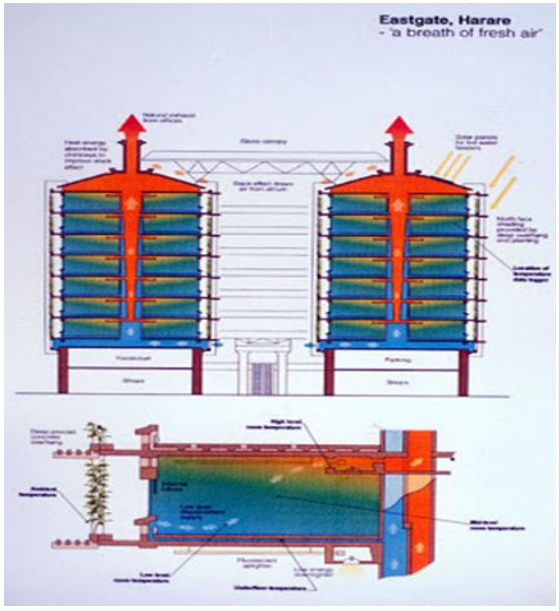


Figure 4.2: Detail illustration how the termite strategy was adapted in the building

Source:www.inhabitat.com/eastgate center

4.4.2 Description Of Design.

i. Site Planning and Landscaping

The structure is so planned in such a way that it blends with the natural topographic formations. The building is so that it is in relation to the site. No cuts or fill, just harmony with nature. Designing the site maintaining the natural landscape elements as much as possible.

ii. Spatial Organization and Design

The structure is an enclosed structure having all spaces all enclosed within envelope.

iii. Dominant Building Materials

The structure is a multi-storey building comprising of different functions made from reinforced concrete, steel, and glass. Different types of screening and glazing systems have been used on the buildings. Materials involved in the screening include, concrete screened walls for lighting and ventilation on the main building, and the use of locally available materials on and around the site.

iii. Energy Sources and Resources; The supply of water is of passive means, rain water collected and stored year round. Electric power is rather passively generated on site from alternative power supply, evident use of photovoltaic cells

iv. Size And Future Expansion

The size of the facility is massive and with no ample space for expansion. This has evidently been due to the engulfment of the building by the development of the city, which has therefore rendered room for future expansion for the facility almost impossible.

v. Aesthetics and Expression

The structures reflect modern type of architectural design with no cultural or any form of local influence in the outlook. The facades are influenced greatly by the quest to achieve thermal comfort by use of thermo-sensitive materials.

Table 4.9 Assessment of the application of Biomimicry principle one in East-gate building

Source: Researcher

BIOMIMICRY PRINCIPLE 1: USE FREE ENERGY			
Variables	**Features**	**Method of application**	**remark**
Energy/power source	integrated photovoltaic facade systems	Building integrated photovoltaic roof panels	positive
	- building integrated wind turbines, wind tunnels and shafts.	Use of chimneys and wind tunnels	positive
Energy management methods	-automated operable windows	Use of automated windows	positive
	-low e-glazing or double panel glazing	Present in building	positive
	-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.	Positive

Table 4.10 Assessment of application of Bio mimicry Principle Two in East-gate building Harare,Zimbabwe.

BIOMIMICRY PRINCIPLE 2: ENHANCE THE BIOSPEHRE			
Variables	**Features**	**Method of application**	**remark**
Source of water	-Effort at harvesting, processing and recycling rainwater.	Use of rain collector and storage	positive
	-use of on-site storm water treatment and ground water recharge	Use of water treatment plant	positive
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.	Site area is pervious to rain water.	positive
Water conservation methods	-on-site treatment plants	Use of water treatment plants	positive

Source: Researcher

Table 4.11 Assessment of application of Bio mimicry Principle three in in East- building Harare,Zimbabwe.

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 ThastyronRastra panels	Used on walls and cladding	positive
Use of building materials with high durability	- use of reinforced concrete, aluminium roofing sheets which are of high durability	-use of reinforced concrete, aluminium 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	Used externally as shading devices	positive
	Control of conductive heat transfer through the building envelope. Thermotropics	Use of thermo-efficient glazing	positive
	Control of interior heat generation, phase change materials	Use of thermo-efficient interior materials	positive
	Secondary energy supply systems and optimization of lighting system	Use of	positive

		photovoltaic panels	

Table 4.12 Assessment of application of Biomimicry Principle four in in East-gate building Harare,Zimbabwe.

BIOMIMICRY PRINCIPLE 4: **ADAPT AND EVOLVE**			
variables	**Features**	**Method of application**	**remark**
Environmental Responsive design features	Day lighting, the use of Skylights.	Use of courtyard system and garden	positive
	Natural ventilation via stackeffect. Sky Gardens.	The use operable windows and provision of fresh air via sky gardens.	Positive
Regenerative site, i **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	-use of waste recycling plants	positive

Source: Researcher

4.4.3 Deductions

From this case, it is evident that so much consideration was given to minimal energy usage in the design. It considered other sources for water and electricity conservation through storm water , water recycling and maximizing natural lighting and ventilation. Looking at tables 4.9-4.12, it shows it clearly.

4.5. **CASE STUDY 4**:Research Laboratory for Experimental Traumatology, Ulm, Germany.

4.5.1 Brief Introduction

The Research Laboratory for Experimental Traumatology is located at Ulm, Germany. It functions as an educational facility. The location has a Tropical moderate climate, characterized by cool winters and warm summers. Its context is urban with an architectural style which is modern. The facilities are conservatory, indoor garden, and laboratories. South-facing conservatories are used to achieve a green, solar architecture, on the south side, they admit sufficient solar heat for subtropical plants to flourish allow the users to benefit fully from sunlight during the winter.



Plate xiv: Conservatory

Source: arch.mcgill.ca

4.5.2: Description of Design

i. Site Planning and Landscaping

The structure is so planned in such a way that it blends with the natural topographic formations. The building is such that, it is in relation to the site. No cuts or fill, just harmony with nature. Designing the site maintaining the natural landscape elements as much as possible.

ii. Spatial Organization and Planning

The structure is an enclosed structure having all spaces enclosed in the envelope.

iii. Dominant Building Materials

Different types of screening and glazing systems have been used on the buildings. Materials involved in the screening include, concrete screened walls for lighting and ventilation on the main building, and the use of locally available materials on and around the site

iii. Energy Sources and Resources.

Walls that collect the sun rays are used. This is to heat up spaces during the winter.The supply of water is of passive means, rain water collected and stored year round, while power is through electrical means.

iv.Size And Future Expansion

The size of the facility is massive and with no ample space for expansion. This has evidently been due to the engulfment of the building by the development of the city, which has therefore rendered room for future expansion for the facility almost impossible.

Table 4.13 Assessment of the application of Biomimicry principle one in Research Laboratory for Experimental Traumatology, Ulm, Germany.

BIOMIMICRY PRINCIPLE 1: USE FREE ENERGY			
Variables	**Features**	**Method of application**	**remark**
Energy/power source	integrated photovoltaic facade systems	Nil	Negative
	- building integrated wind turbines, wind tunnels and shafts.	Nil	Negative
Energy management methods	-automated operable windows	Use of automated windows	positive
	-low e-glazing or double panel glazing	Present in building	positive
	-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	Nil	Negativee

Source: Researcher

Table 4.14 Assessment of application of Bio mimicry Principle Two in Research Laboratory for Experimental Traumatology, Ulm, Germany.

BIOMIMICRY PRINCIPLE 2: ENHANCE THE BIOSPEHRE			
Variables	**Features**	**Method of application**	**remark**
Source of water	-Effort at harvesting, processing and recycling rainwater.	Nil	Negative
	-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.	About 80% of total site area is pervious to rain water.	positive
Water conservation methods	-on-site treatment plants	Use of water treatment plants	positive

Source: Researcher

Table 4.15 Assessment of application of Bio mimicry Principle three in Research Laboratory for Experimental Traumatology, Ulm, Germany.

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 ThastyronRastra panels	Used on walls and cladding	positive
Use of building materials with high durability	- use of reinforced concrete, aluminium roofing sheets which are of high durability	-use of reinforced concrete, aluminium 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	Used externally as shading devices	positive
	Control of conductive heat transfer through the building envelope. Thermotropics	Use of thermo-efficient glazing	positive
	Control of interior heat generation, phase change materials	Use of thermo-efficient interior materials	positive
	Secondary energy supply systems and optimization of		

	lighting system	Use of photovoltaic panels	positive

Source: Researcher

Table 4.16 Assessment of application of Biomimicry Principle four in Research Laboratory for Experimental Traumatology, Ulm, Germany.

BIOMIMICRY PRINCIPLE 4: **ADAPT AND EVOLVE**			
variables	**Features**	**Method of application**	**remark**
Environmental Responsive design features	Day lighting, the use of Skylights.	Use of south facing conservatories to trap sun light	positive
	Natural ventilation via stackeffect. Sky Gardens.	The use operable windows.	Positive
Regenerative site, i **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



Plate xv: Inside the conservatory

Source: http://www.arch.mcgill.ca/schempp.html, 2001).

4.5.3 Deductions

From this case, it is shows that much was not considered in terms of using free energy for power supply. Table 4.13 shows that, while in regards to enhancing the biosphere, energy and material usage much was considered. See tables 4.14-4.16.

4.6 CASE STUDY 5: COUNCIL HOUSE 2 (CH2) BUILDING, MELBOURNE

4.6.1 Brief Introduction

Council House 2 (also known as **CH_2**), is an office building located at 240 Little Collins Street in the CBD, in Melbourne, Australia. It is occupied by the City of Melbourne council, and in April 2005, became the first purpose-built office building in Australia to achieve a maximum Six Green Star rating, certified by the Green Building Council of Australia. CH_2 officially opened in August 2006.



Plate xvi: Exterior view of the building

Source: skyscrapercity.com/ch2 building

4.6.2 Description of Building Design

Bio mimicry was a large component in designing the building. The building's principal design architect, Mick Pearce, incorporated a system previously and successfully used in the Eastgate Centre in Harare. The heating, ventilating, and cooling system (hvac) is designed with strategies taken from a termite mound. In the termite mound, the cool wind is drawn into the base of the mound, via channels and the 'coolth' is stored using the soil. As the air warms, it flows upwards and out of the mound via vents. This gives the mound the ability to keep a stable temperature. CH_2 uses similar strategies with its system by effectively using natural convection, ventilation stacks, thermal mass, phase change material, and water for cooling. Another strategy used taken from nature is the skin system. The façade is composed of an epidermis (outer skin) and dermis (inner skin). The 'dermis' of the building consists of the outside zone to house the stairs, lifts, ducts, balconies, sunscreens and foliage with the inner line defining the extent of the 'fire compartment'. The dermis was designed with lightweight constructing using a steel frame. The epidermis provides the micro-environment including the primary sun and glare control for the building while creating a semi enclosed micro-environment.

Ventilation stacks are implemented on the north and south façades of the building. These stacks are used to channel air. The north stacks receive more sun so they are black to absorb heat, which in turn encourages the warm air from the building to rise up out of the stacks. The south stacks are used to channel down cold air through the vents. These stacks also offer shading for office windows.



Plate xvii: Detail of the shutters on the northern façade

Source: skyscrapercity.com/ch2 building



Plate xviii: Eastern side and rooftop turbines

Source: skyscrapercity.com/ch2 building

i. Site Planning and Landscaping

The structure is so planned in such a way that it blends with the natural topographic formations. The site design maintains the natural landscape elements as much as possible.

ii. Spatial Organization and Design

The structure is an enclosed structure having all spaces all enclosed within the envelope.

iii. Dominant Building Materials

The structure is a multi-storey building comprising of different functions made from reinforced concrete, steel, and glass. Different types of screening and glazing systems have been used on the buildings. Materials involved in the screening include, concrete screened walls for lighting and ventilation on the main building, and the use of locally available materials on and around the site.

iii. Energy Sources and Resources; The supply of water is of passive means, rain water collected and stored year round. Electric power is rather passively generated on site from alternative power supply, evident use of rooftop turbines.

iv. Size And Future Expansion

The size of the facility is massive and with no ample space for expansion. This has evidently been due to the engulfment of the building by the development of the city, which has therefore rendered room for future expansion for the facility almost impossible.

vi. Aesthetics and Expression

The structures reflect modern type of architectural design with no cultural or any form of local influence in the outlook. The facades are influenced greatly by the quest to achieve thermal comfort by use of thermo-sensitive materials and shading.

Table 4.17 Assessment of the application of Biomimicry principle one in (CH2) Buiding, Melbourne

BIOMIMICRY PRINCIPLE 1: USE FREE ENERGY			
Variables	**Features**	**Method of application**	**remark**
Energy/power source	integrated photovoltaic facade systems	Nil	Negative
	- building integrated wind turbines, wind tunnels and shafts.	Use of chimneys and wind tunnels	positive
Energy management methods	-automated operable windows	Use of automated windows	positive
	-low e-glazing or double panel glazing	Present in building	positive
	-structural insulated panels and other high performance insulated concrete panels	structural insulated panels on building envelope	Positive

Source: Researcher

	use of courtyard garden and pool of water to moderate the micro climate	Passive cooling technique, plants.	Positive

Table 4.18 Assessment of application of Bio mimicry Principle Two in (CH2) Buiding, Melbourne

BIOMIMICRY PRINCIPLE 2: ENHANCE THE BIOSPEHRE			
Variables	**Features**	**Method of application**	**remark**
Source of water	-Effort at harvesting, processing and recycling rainwater.	Use of rain collector and storage	positive
	-use of on-site storm water treatment and ground water recharge	Use of water treatment plant	positive
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.	Site area is pervious to rain water.	positive
Water conservation methods	-on-site treatment plants	Use of water treatment plants	positive

Source: Researcher

Table 4.19 Assessment of application of Bio mimicry Principle three in (CH2) Buiding, Melbourne

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 ThastyronRastra panels	Used on walls and cladding	positive
Use of building materials with high durability	- use of reinforced concrete, aluminium roofing sheets which are of high durability	-use of reinforced concrete, aluminium 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	Used externally as shading devices	positive
	Control of conductive heat transfer through the building envelope. Thermotropics	Use of thermo-efficient glazing	positive
	Control of interior heat generation, phase change materials.	Use of thermo-efficient interior materials	positive
	Secondary energy supply systems and optimization of lighting system	Use of photo-voltaic panels.	positive

Source: Researcher

Table 4.20 Assessment of application of Biomimicry Principle four in (CH2) Buiding, Melbourne

BIOMIMICRY PRINCIPLE 4: **ADAPT AND EVOLVE**			
variables	**Features**	**Method of application**	**remark**
Environmental Responsive design features	Day lighting, the use of Skylights.	Use of skylights system	positive
	Natural ventilation via stackeffect. Sky Gardens.	The use operable windows and provision of fresh air via sky gardens.	Positive
Regenerative site, i **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	-use of waste recycling plants	positive

Source: Researcher

4.6.3 Deductions

From this case, it is evident that so much consideration was given to minimal energy usage in the design. It considered other sources for water and electricity conservation through storm water ,

water recycling and maximizing natural lighting and ventilation. Looking at tables 4.17-4.20, it shows it clearly.

S/N	CASE STUDY	PRINCIPLE 1	PRINCIPLE 2	PRINCIPLE 3	PRINCIPLE 4	REMARKS
1	Fac. Of Med., KASU	Fair	Good	Poor	Good	Fair
2	Fac. Of Med., A.B.U	Fair	Good	Poor	Good	Fair
3	Eastgate, Zimbabwe	Excellent	V.Good	Excellent	Excellent	V.Good
4	Research Lab., Ulm	Good	Good	Excellent	V.Good	Good
5	CH2 House	V.Good	Excellent	Excellent	Excellent	V.Good

Table 4.21: Summary of Case Study Findings on the Reflection of Biomimicry Principles

Source: Researcher

Rating = Excellent (5) Very good(4) Good(3) Fair (2) Poor(1)

4.7 Summary of Findings From Case Studies

In general the findings made from case studies can be summarises as follows

i. All the case studies utilises the use of natural lighting and ventilation more than artificial means by providing cross ventilation and enough operable windows.

ii. The materials used in all 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. Most of the foreign case studies looked to alternative energy sources especially renewable sources. The local cases did not take much cognizance to renewable energy sources.

iv. All the cases do not have spaces for future expansion, they have a compact site that do not have enough spaces for natural features.

Therefore, it is required that for facilities of this nature, consideration should be given to locally produced materials and technology. Alternative sources for energy and water generation should be given priority because of its gains in terms of reducing the operational cost of the facility.

CHAPTER FIVE

DESIGN REPORT

5.1 AREA OF STUDY

The study area is Kaduna state, north central of Nigeria. The state was created on 27th May 1967 as one of the six states of the northern region of Nigeria. The state capital is Kaduna with 23 local government areas. Kaduna covers a total area of about 46,053 km². Fig 5.1 shows its geographical location within the country .

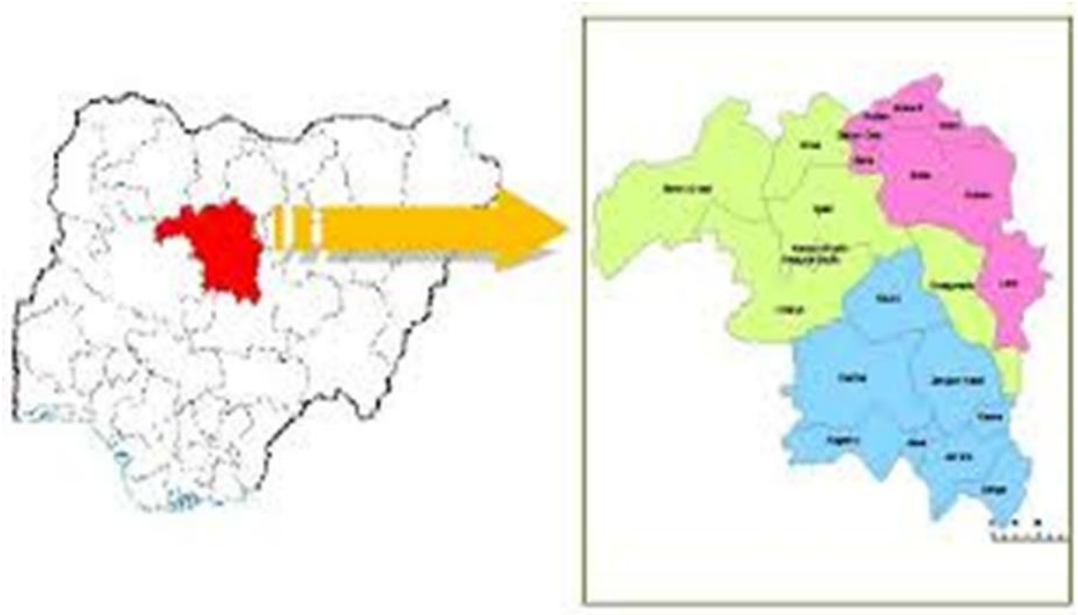


Figure 5.1: Map of Nigeria showing Kaduna State
Source: maps.google.com.ng

5.2 CLIMATIC DATA OF KADUNA

1. Climate Type

Kaduna State experiences a typical tropical continental climate with distinct seasonal regimes, oscillating between cool to hot dry and humid to wet. These two seasons reflect the influences of tropical continental and equatorial maritime airmasses which sweep over the entire country.However, in Kaduna State, the seasonality is pronounced with the cool to hot dry season being longer, than the rainy season. Again, the spatial and temporal distribution of the rain varies, decreasing from an average of about 153mm in Kafanchan-Kagoro areas in the Southeast to about 101mm in lkaraMakarfi districts in the northeast.

2. RAINFALL

Kaduna is in the moderate humid belt of Nigeria. The start of rainy season is around March. The duration of the rainy season therefore varies from about 240 days to about 190 days in. The total annual precipitation varies considerably from year to year between 121mm and 280mm. It is normally concentrated in the months of July, August and September. This concentration of rainfall shows the need for drainage systems that can handle large volumes of water very

quickly.Therefore, drainages are to be designed to handle large volume of water flow rapidly and forces of the lines of squally should be taken into consideration.

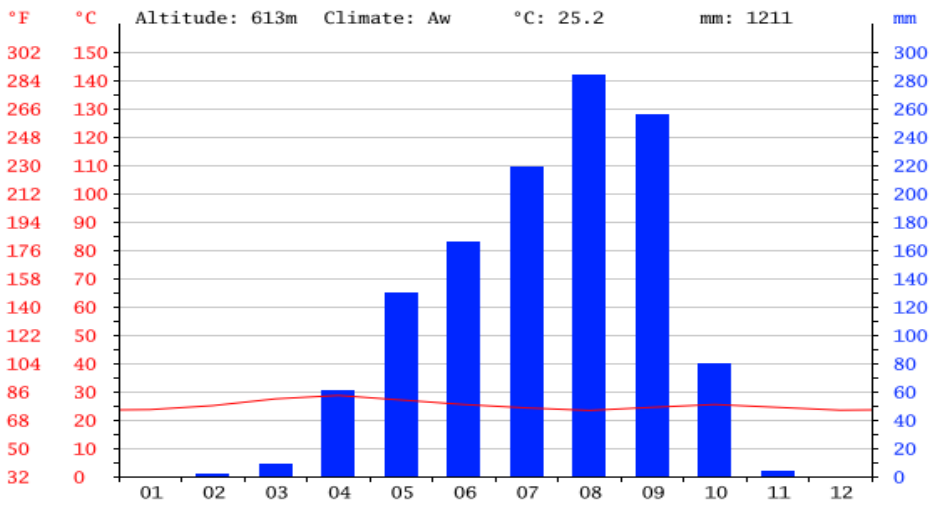


Fig: 5.2 Kaduna Monthly Rainfall and precipitation 2015.
Source; www.climate data.org

3. Temperature

The area has maximum temperature of 35.3^{o}C in the months of April while the minimum is 23.3^{o}C in the month of December and August is the coldest. (Plate 5.5 shows climatic analysis). The tropical comfort zone is on latitude 231/2^{o}N. Upper comfort limit for tropics is 27%, while the lower comfort limit for tropics is 22^{o}C.Thus, use of soft landscape elements should be

introduced within the surrounding. Orientation of structures with consideration towards tilting of the longer side of the building to face north and south but where it is not possible , trees will be planted to cut the intensity of the heat.

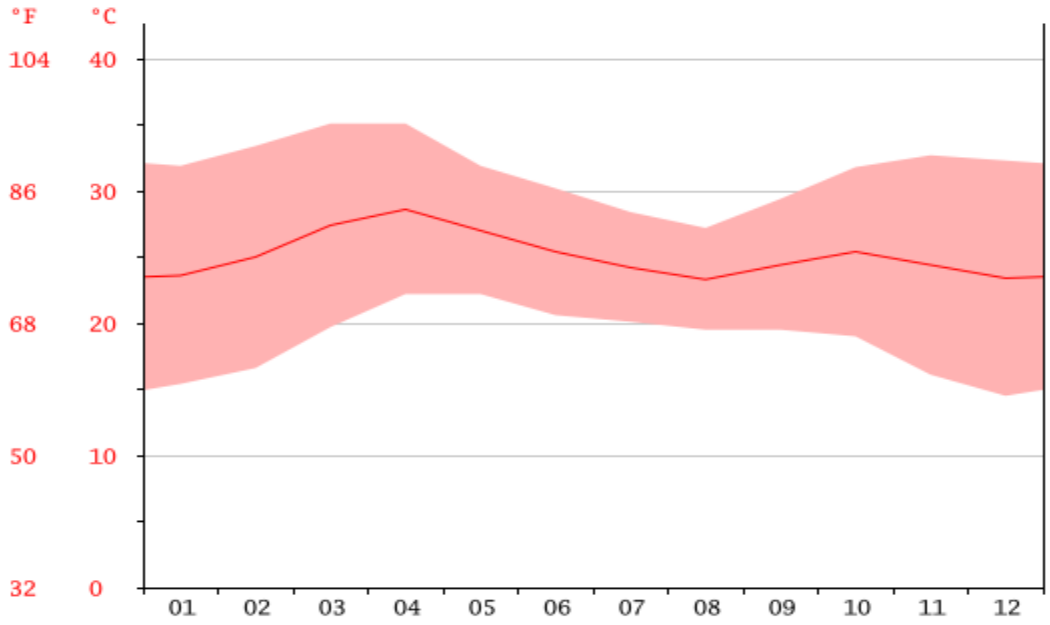


Fig: 5.3Kaduna Monthly Temperatures 2015.
Source; www.climate data.org

4. Wind

Two major air masses dominate Kaduna State: The Tropical Maritime air mass and the Tropical Continental Air Mass. The Tropical Maritime Air Mass is formed over the Atlantic Ocean of the South of the country and is therefore warm and moist. It blows from South-West to North-East the tropical continental is developed over the Sahara desert and thus is warm and dry and blows from North-East to South-West. The Tropical Continental Air Mass comes with the dry season while the Tropical Maritime Air Mass, the wet season.Hence, trees will be planted as

windbreakers on site and openings will be provided with due considerations to wind direction and building orientation.

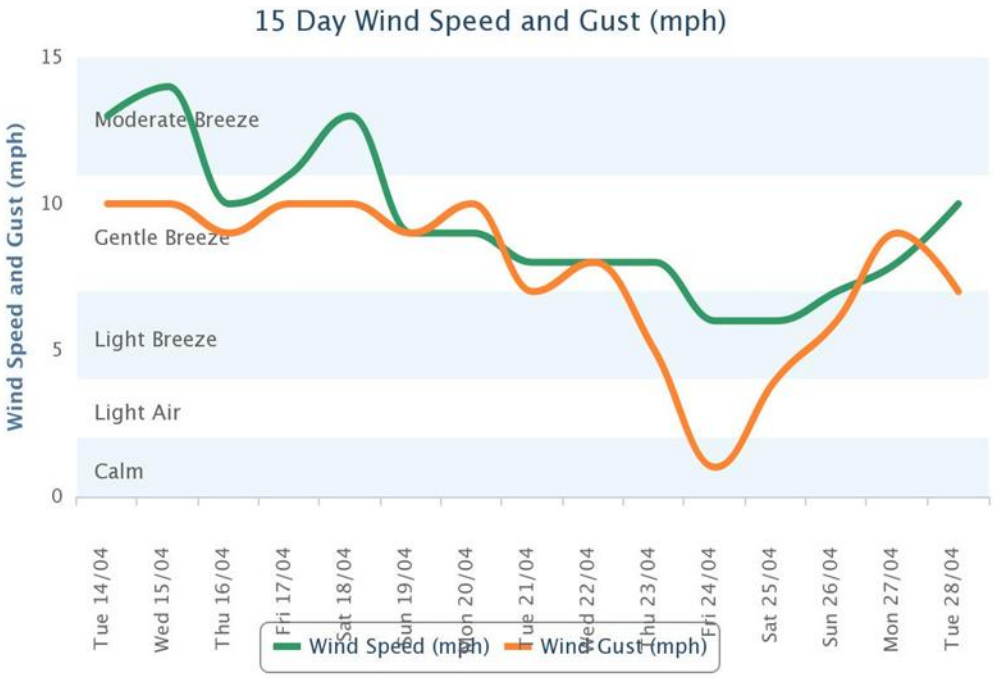


Fig: 5.4 day wind speed in kaduna 2015.
Source;www.worldweather.com/kaduna

5. Vegetation

Kaduna falls within the geographical region of the north central highland with a tropical continental climate. It has a savannah type vegetation characterized by plenty grasses and deciduous trees which are about 10-15m.over the years the ground cover has reduced due to human activities such as farming, bush burning and grazing. Thus, trees and shrubs on sites should be retained to control erosion and modify the micro climate of the site.

5.3SITE ANALYSIS

5.3.1 SITE LOCATION

The site is located in Kaduna State University, Kaduna. Kaduna town lies on Latitude 10° $31^{1}08.52^{11}$ N and 7° 26^{1} 56.33^{11} E (Google earth, 2015), and from Nigerian point of view, Kaduna town is located in Kaduna State, in the North Central region of the country.



Figure 5.5: Map of Kaduna State

Source: maps.google.com.ng

5.3.2 Facts and Figures Kaduna State University, Kaduna

Development Area - over 295hectres (295000 square meterapprox) Existing facilities in the university include; Administrative block, 2 no Faculty Building (Medicine and Sciences) University Library, Clinic, Student Hostel, Central Market, Estate Department Building, however there were services facilities in the university which include, Power Line, Water Supply, Access Roads Telephone Services.

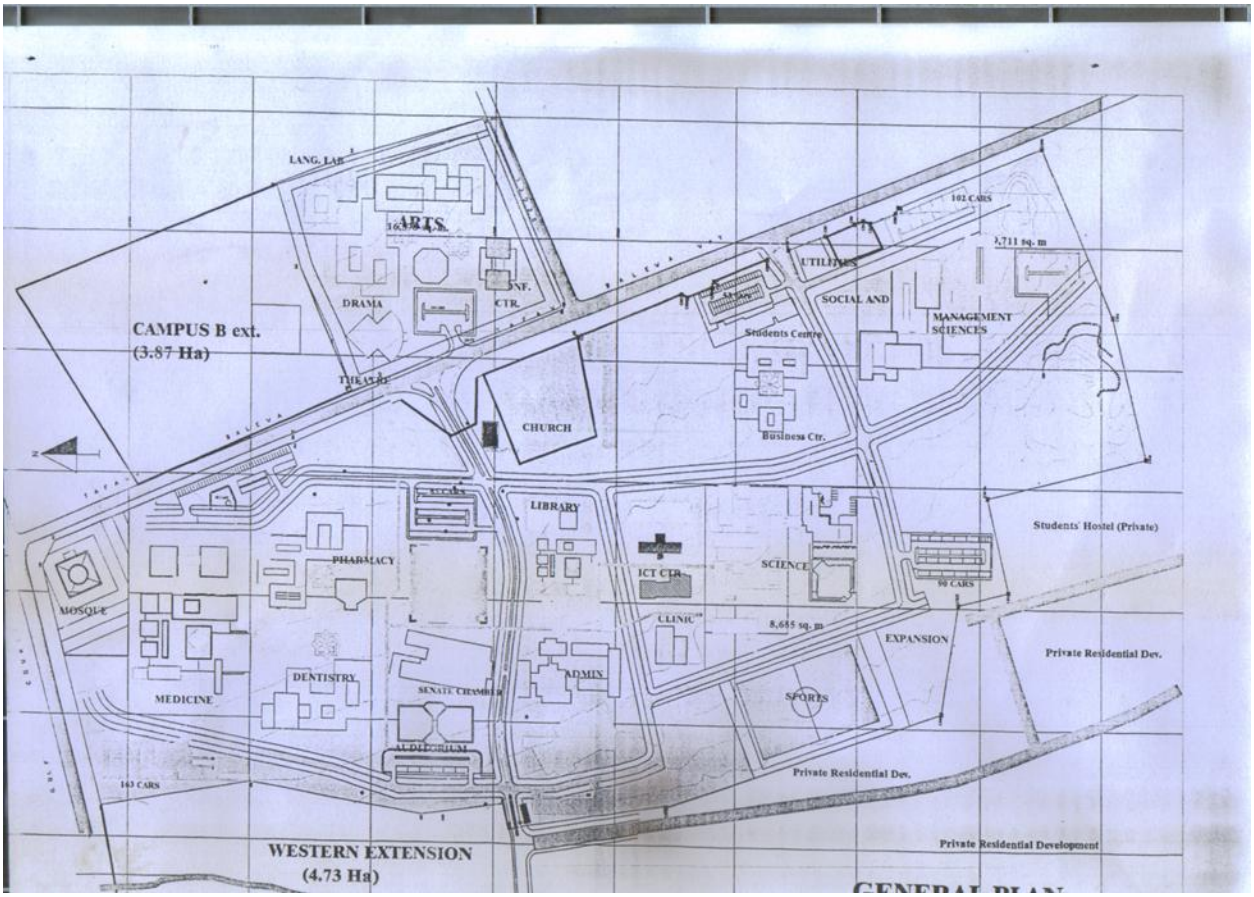


Figure 5.6: KASU Master Plan (Source: KASU Physical planning office)

5.3.3SITE SELECTION CRITERIA

The sites were chosen from two different locations within the Kaduna State University and were tested against Suitability against several variables, to allow for the selection of the best site, a

weighting system was developed to aid in the selection. The table below gives the weighting scale developed. Each criterion is given a weight as the table 5.1 below shows.

(i) Site features

(ii) Orientation

(iii) Size of site and possibility for future expansion

(iv) Land use compliance

(v) Visual and aesthetics compliance

(vi) Proximity to other facilities

(vii) Accessibility (traffic issue)

The scale varies from 1 to 4 points corresponding with 2 representing Poor, 3-Fair, 4- Very Good and 5-Excellent respectively.

Table 5.1 Comparative Analysis of the Sites

S/No	CRITERIA	SITE A	SITE B	REMARKS
1.	Site features	5	3	
2.	Orientation	4	2	
3.	Size of site and possibility for future expansion	5	3	
4.	Land use compliance	3	5	
5.	Visual and aesthetics compliance	3	3	
6.	Proximity to other facilities	4	4	
7.	Accessibility (traffic issue)	4	4	Equal Access
	Total =	31	**28**	

Source: Researcher, (2015)

From the computations and summary of results, Site A has been chosen as the site for the proposed project.

5.3.4 Physical Features of Site.

1. Traffic and Access

The chosen site is bounded on the north by a dual carriage road parallel to the site. This roadway would be likely the highest generator of noise. To the west and East leading to the library and back to the admin office to the academic planning unit, more trees will be planted in that direction to reduce that effect.

2. Noisy Zone

The noise is generated by moving vehicles from the eastern side; more trees shall be planted in the direction to serve as a buffer for noise reduction.

3. Topography

The site is plat with gently sloped to ward, south and north east direction, drainage should be provided in that direction.

4. Site Trees

The site is characterized of few trees, scatted at the north east and south west of the site, which is inadequate. More trees shall be planted.

5. Site Shrubs and Grasses

Site shrubs and grasses are typical of stratified community with a discontinuous canopy shrubs, scattered all over the site proffer site planning and landscaping shall be made with a view to providing passive means of cooling the heat load.

6. Site Soil

The site is characterized by reddish brown soil at top soil level, proper structural analysis should be provided to take care of different soil formation especially in the selection of foundation type. See figures 5.7-5.9 for graphical presentations of the above character of the site.

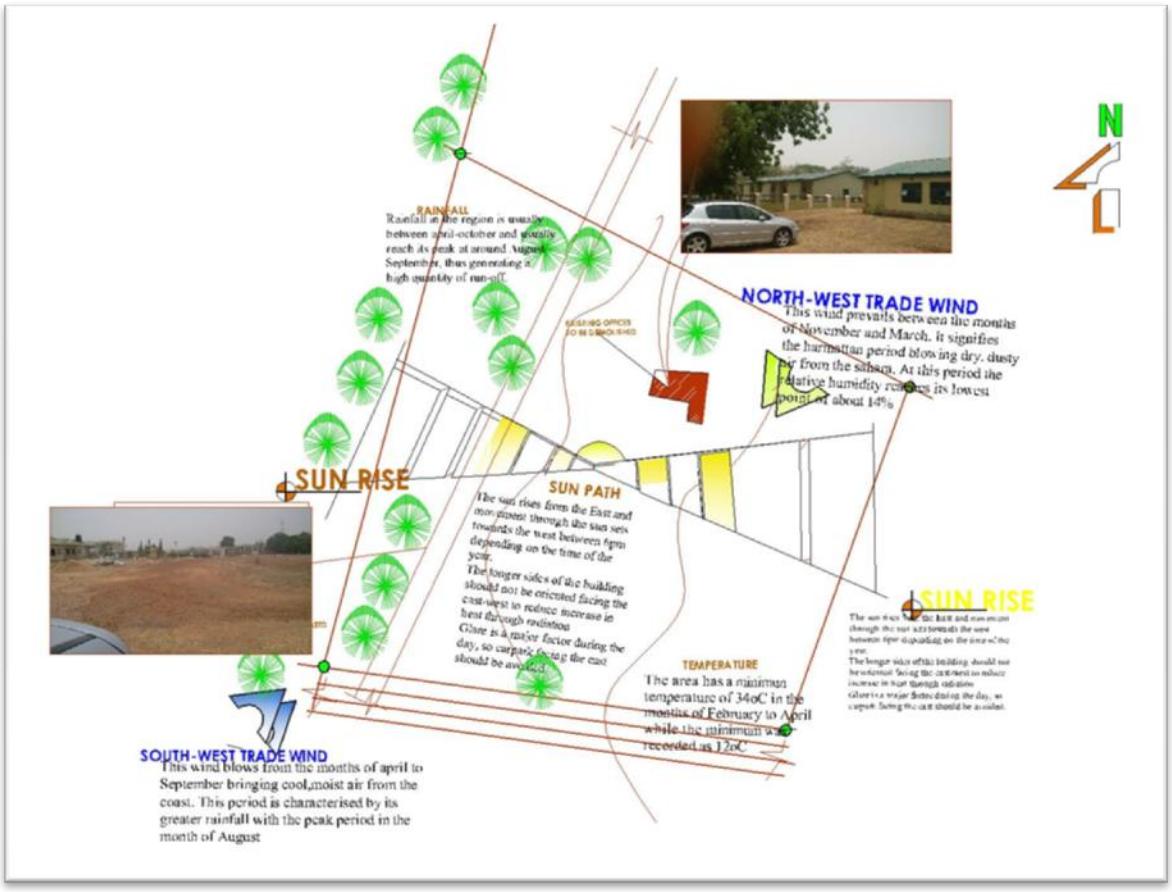


Fig. 5.7 Site analysis

Source: Researcher, (2015)

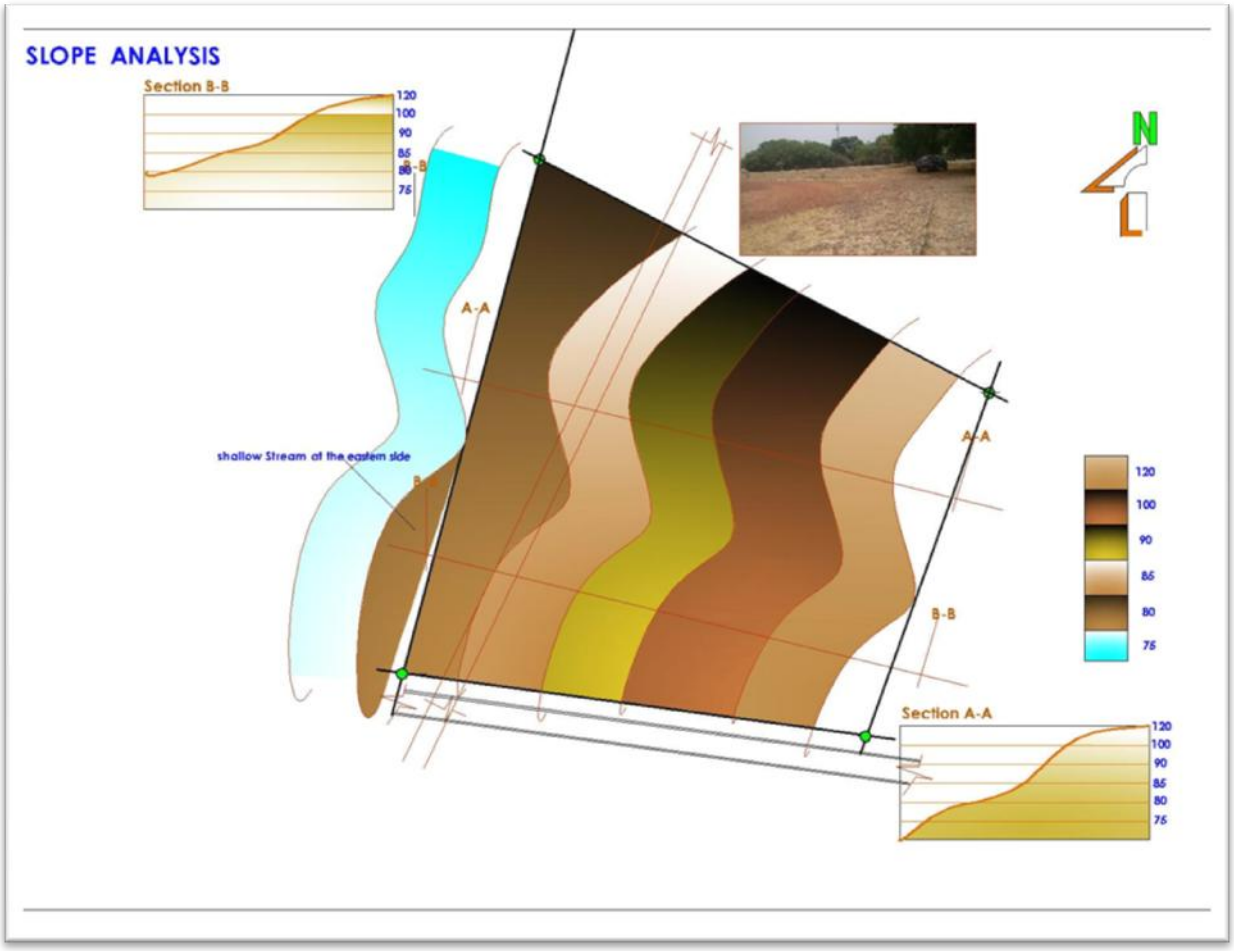


Fig. 5.8 Site Topography

Source: Researcher, (2015)

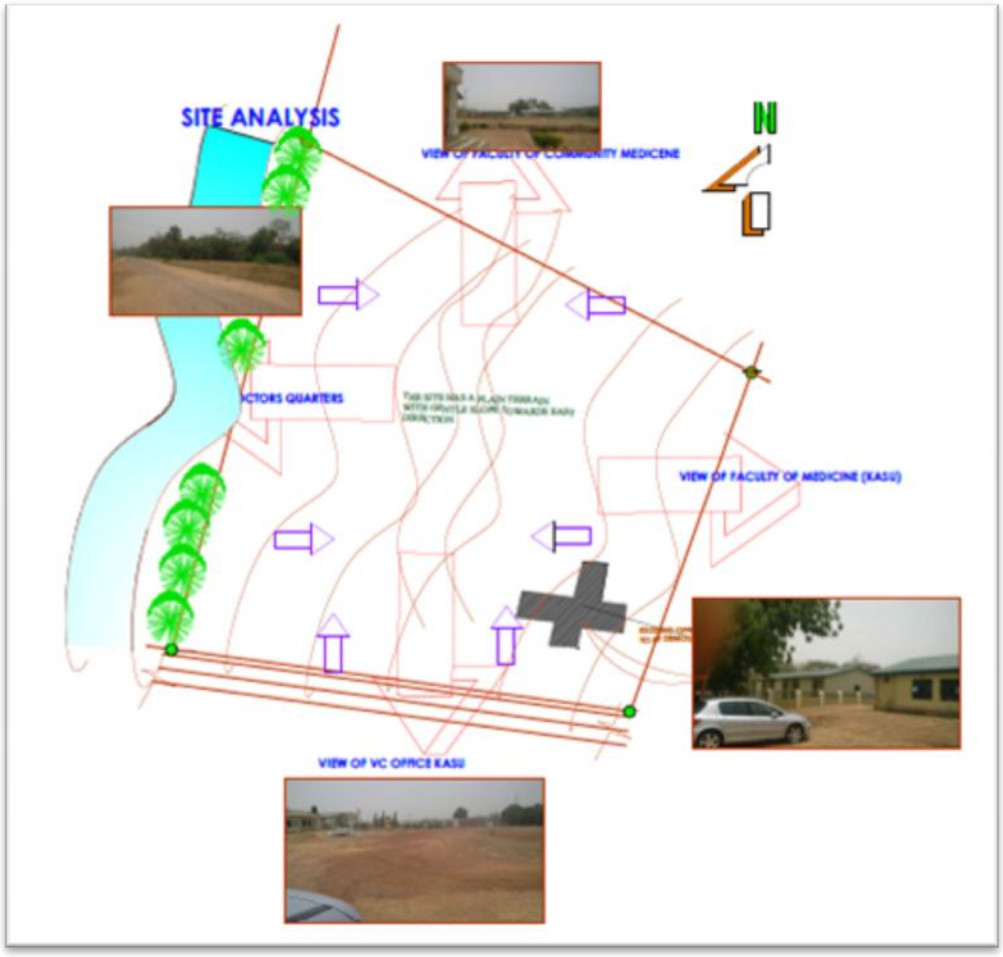


Fig. 5.9 Site View

Source: Researcher, (2015)

5.4DESIGN PARAMETERS FROM THE SITE ANALYSIS

From the site analysis conducted, the following parameters shall be used in the design proposal:

i. Access into the site shall be via the one access road.

ii. The orientation of the building shall be done to maximize natural lighting and ventilation.

iii. Existing tress shall be retained and more shall be planted in order to create a shade onsite especially along pedestrian walkways. Tress shall also be used to define the boundary of the site.

5.5 DESIGN BRIEF AND DEVELOPMENT

5.5.1 Brief Development

This thesis focuses on the design of a Faculty of Medicine Kasu, which reflects the concept of Biomimicry. The Faculty of Medicine for Kaduna State University is going to be for pre-clinical studies and is meant to create a working and learning environment that provides inspiration for students and staff, contributing to their well being and supporting them to achieve their full potential. The design features of the this Faculty will be described with respect to the spatial organization and Biomimetic design principles applied in the faculty design. This is to more clearly elucidate the reasons for certain elements featured in the design of the Faculty of medicine. The design brief is therefore developed based on the findings from case studies conducted and the basic guidelines for designing a pre-clinical medical school.

5.5.2The School Population

The population of the faculty comprises mainly of staff and students table 5.2 below shows the student intake and the ultimate capacity.

TABLE-5.2: Student's Population Structure for Faculty of Medicine (Pre-Clinical)

Course	Duration	Student Intake	Ultimate Capacity	Total
Anatomy	4 Years	80	100	400
Physiology	4Years	80	100	400
Comm. Med.	4Years	80	100	400
MBBS	3Years	80	100	300

TABLE-5.3: below shows the staff student ratio which is 1:15 as stipulated

Department	Staff/Student Ratio	Student Population	Number of Staff
Anatomy	1:15	400	27
Physiology	1:15	400	27
Comm. Med	1:15	400	27
MBBS	1:15	300	20

Source: Using NUC Guidelines for Medicine
All design schedules shall be based on ultimate capacity

TABLE-5.4: NUC staff-student ratio of 1:5 for engineering with non-academic

Department	Student Population	Academic Staff	Non-Academic Staff	Total Staff
Anatomy	400	22	5	27
Physiology	400	22	5	27
Comm. Med.	400	22	5	27
MBBS	300	16	4	20

Source: Using NUC Guidelines for Medicine

TABLE-5.5: NUC staff ratio academic with non-academic staff

Department	Academic staff total	Professors 20%	Senior lecturers 35%	Junior lecturers 45%
Anatomy	22	4	8	10
Physiology	22	4	8	10
Comm. Med.	22	4	8	10
MBBS	16	3	6	7
Total	82	15	28	37

Source: Using NUC Guidelines for Medicine (Pre-Clinical)

5.5.3 Space Allocation

This is the space allocation for the different teaching learning and social spaces. Space allocation was conducted for students, lecturers and anticipated volume of visitors using the NUC standards as a guide. For the good administration of each discipline, adequate facilities are to be provided for the office of the dean and each of the departments the required minimum standard for each department includes: seminar rooms lecture rooms/theatres, laboratories, exhibition spaces, library, computer rooms, parking spaces and toilet facilities.

TABLE 5.6: Deanery Schedule of Accommodation

S/No	Space	ea per Person (m^2)	Number of Persons	Floor Area m^2
1.	Dean	24	1	24
2.	Deputy Dean	20	1	24
3.	Personnel Assistant to Dean	16	1	16
4.	Assistant Dean	20	1	20
5.	Faculty Secretary	20	1	20
6.	General Office	4	4	16
7.	Faculty Board Room	2	26	52
8.	Toilets Facilities	2	4	8
	Total =	288	39	180

Source: Using NUC Guidelines for Medicine

TABLE 5.7: Department of Anatomy Schedule of Accommodation

S/No	Space	Area per Person (m^2)	Number of Persons	Floor Area m^2
1.	Professor	24	4	120
2.	Head of Department	24	1	24
3.	Personnel Assistant to H.O.D.	16	1	16
4.	Senior Lecturer	20	9	140
5.	Junior Lecturer	16	13	144
6.	Technical Staff	6	3	18
7.	Administrative Staff	6	4	24
8.	Studio Space	3	500	1500
9.	Lecture Room	0.5	500	250
10.	Seminar Room	0.5	100	50
11.	Library	2	150	300
12.	Dissection hall	2	100	200
13.	Laboratory	10	320	640
14.	Storage Space	0.5	80	40
15.	Toilet Facilities	2	10	20
16.	Social Spaces	0.5	100	50
	Total =	**125**	*1996*	**3536**

Source: Using NUC Guidelines **for** Anatomy

TABLE 5.8: Dept of Chemical Engineering Schedule of Accommodation

S/No	Space	ea per Person (m^2)	Number of Persons	Floor Area m^2
1.	Professor	24	5	120
2.	Head of Department	24	1	24
3.	Personnel Assistant to H.O.D.	16	1	16
4.	Senior Lecturer	20	9	180
5.	Junior Lecturer	16	13	208
6.	Technical Staff	6	4	24
7.	Administrative Staff	6	3	18
8.	Studio Space	3	100	300
9.	Lecture Room	0.5	500	200
10.	Seminar Room	0.5	100	40
11.	Library	2	100	200
12.	Laboratory	2	200	400
13.	Computer Room	2	100	200
14.	Storage Space	0.5	80	40
15.	Toilet Facilities	2	20	40
16.	Social Spaces	0.5	80	40
17.	Conference Room	2	21	42
	Total =	**125.5**	**1257**	**2092**

Sources: Using NUC Guidelines for Medicine

TABLE 5.9:Dept of Physiology Schedule of Accommodation

S/No	Space	ea per Person (m^2)	Number of Persons	Floor Area m^2
1.	Professor	24	4	120
2.	Head of Department	24	1	24
3.	Personnel Assistant to H.O.D.	16	1	16
4.	Senior Lecturer	20	9	180
5.	Junior Lecturer	16	13	208
6.	Technical Staff	6	4	24
7.	Administrative Staff	6	3	18

8.	Studio Space	3	100	300
9.	Lecture Room	0.5	500	250
10.	Seminar Room	0.5	100	50
11.	Library	2	100	200
12.	Laboratory	2	200	400
13.	Computer Room	2	100	200
14.	Storage Space	0.5	80	40
S/No	Space	ea per Person (m2)	Number of Persons	Floor Area m2
15.	Toilet Facilities	2	20	40
16.	Social Spaces	0.5	80	40
17.	Conference Room	2	21	42
18.	Workshops	2	100	200
	Total =	127.5	1437	2352

Source: Using NUC Guidelines for Medicine

TABLE 5.10: Dept of Community Medicine Schedule of Accommodation

S/No	Space	ea per Person (m^2)	Number of Persons	Floor Area m^2
1.	Professor	24	5	120
2.	Head of Department	24	1	24
3.	Personnel Assistant to H.O.D.	16	1	16
4.	Senior Lecturer	20	9	180
5.	Junior Lecturer	16	13	208
6.	Technical Staff	6	4	24
7.	Administrative Staff	6	3	18
8.	Studio Space	3	80	240
9.	Lecture Room	0.5	400	200
10.	Seminar Room	0.5	100	50
11.	Library	2	100	200
12.	Laboratory	4	160	320
13.	Computer Room	2	80	160
14.	Storage Space	0.5	80	40
15.	Toilet Facilities	2	20	40
16.	Social Spaces	0.5	80	40
17.	Conference Room	2	21	42
18.	Workshops	2	160	320

	Total =	**127.5**	**2367**	**2242**

Source: Using NUC Guidelines for Medicine

TABLE-5.11: Lecture Theatres Schedule of Accommodation

S/No	Space	Area per Person (m^2)	Number of Persons	Floor Area m^2
1.	Stage			
2.	Students	0.5	800	400
3.	Backstage			

Source: Using NUC Guidelines for Medicine

5.6 CONCEPT FORMULATION

Concept is a guiding principle of a thought or an idea relating to something abstract. Concept architecturally, is a series of intentions or solutions originated in the mind to solve a particular architectural problem while considering other design factors.

5.6.1 Site Zoning Concept

The site is zoned based on noise generation, Public zone; Semi Public and Quite zone. The noise source is basically from Northern part.

1. Public zone includes;
    (i) Lecture Theaters
    (ii) Parking Spaces
    (iii) Delivery Bay
    (iv) Laboratory
    (v) Student Common Facilities

2. Semi Public areas include;

(vi) Lecture Theatres

(vii) Lecture Rooms

(viii) Computer Laboratory

(ix) Auxiliary Units

3. Quite area includes;

(a) Data Rooms

(b) Conference Rooms

(c) Lecturers Office

5.6.2 DESIGN CONCEPT

The concept adopted for this project is the use of natural shape and form of a plant leaf and its protruding flowerin the form of compact design in architecture. Some of the basic attribute of these forms to be taken advantage of in the execution of this task is the character of biological forms, and its applicability in design. These characteristics include its pleasing appearance which can be translated to aesthetics in design, flexibility and ability to flow with the natural physical environment, and its amazing physical and structural integrity (see figure 5.10).

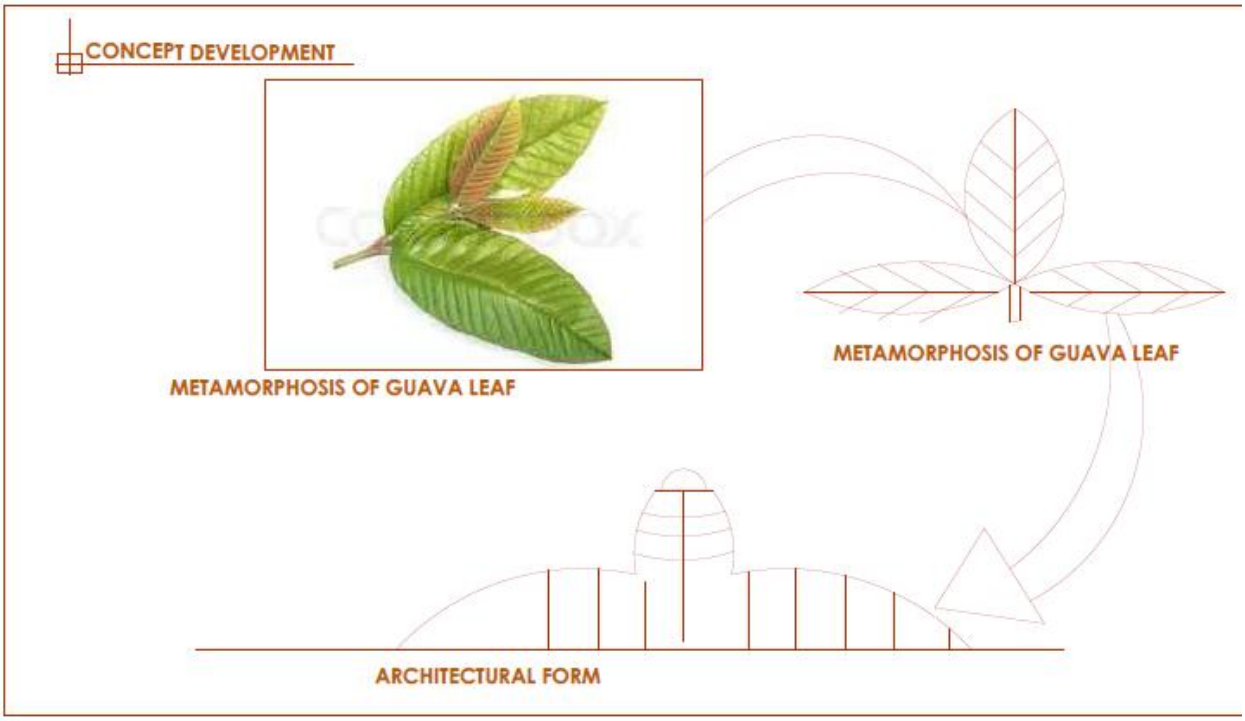


Figure 5.10: Showing design concept formulation.

Source: Author's work

5.6.3 Site plan concept

The site concept is a Biomimetic synthesis. The concept is based on the zoning of the faculty complex into three parts: General outdoor gardens, Adjunct facilities and Classroom/office/laboratory units. The following criteria were also considered;

I. **Safety** - The need to give much consideration to the pedestrian circulation. Hence a design that provides a free pedestrian environment. This will provide a safe environment for patients.

II. **Site configuration** - The site is relatively flat and all data relating to the site analysis were concerned, that is, point of penetration, natural features and site line .

III. Circulation - Movement from one zone to the other while experiencing activities as a continuous whole.

5.7 DESIGN CONSIDERATION

Adequate planning of educational facilities is very essential to ensure efficient productivity of staff and learning environment of students. Therefore basic design parameters must be used to ensure comfort, safety, efficiency and productivity of staff and students.

5.8 ARCHITECTURAL DESIGN OF THE PROPOSED FACULTY OF MEDICINE

The design is aimed at adopting a biomimetic design approach into the design of the faculty of medicine for Kaduna State University due to the role nature plays in providing solutions to built environment challenges especially in terms of energy efficacy. To achieve this, the natural shape and form of a plant leafwith an outshoot of its flower were integrated to have a building form that will maximize natural lighting and natural flow of air. It's applications in the design are discussed under the following elements.

1: Use of free energy

i. Use of integrated photovoltaic façade systems

ii. Use of Thastytronrastra panels on the exterior

iii. Use of stack effect in cooling the building

2: Enhancing the biosphere

i. Retention of rain storm water and on site filtration

ii. Storage of rain water to serve as water supply via the use of water treatment plant and recycling plant

ii. Retention of plants native to the site and planting more where necessary

3: Use of minimal energy and material

i. Use of reinforced concrete roof decking in some part of the building

ii. Use of suspended particle board ceiling in offices and laboratories

iii use of recycle building materials, such as thastyronrastra panels and photovoltaic panels on the exterior envelopes

4: Adapt and evolve

i. The use of trees shrubs, and hedges to enhance the micro climate and also to control soil erosion. Most of the vegetation has been maintained and planted

ii. The use of skylight and courtyards

iii The use of stack in the building to improve the quality the building



Figure 5.11:Application of photo voltaics on building facades.

Source: Author's work



Figure 5.12:Showing application of window shutters on building facade of the proposed project.
Source: Author's work

5.8.1 Functional Relationships in the Proposed Faculty of Medicine, Kaduna State University.

1. Site Planning and Landscaping

The site planning takes into consideration the natural features afforded by the site and incorporate them into the design to achieve harmony between the site and the building. Buildings are arranged to follow the natural topography of the site by way of creating split levels.On approach into the site, one will encounter the general parking spaces on the left and right side of the site,with the general entrance of the medical school directly in front for visual appreciation. The pedestrian and vehicular routes were therefore planned to ensure this without traffic conflict (see figure 5.13).

z



Figure 5.13: Site plan of the proposed project.

Source: Author's work

2. Floor plans

It is a simple dynamic shape that facilitates circulation, and air movement within the building form. The facility has two floors that follows the topography of the site. The floor plan consists of a central core, four wings that radiate from the central core and a theatre. On the ground floor, the first point is the reception, then to the left and right are wings of the building from the approach view. The left wing contains the library unit while to the right are offices spaces.

Further up the reception area is the central core which contains the deanery. At rear part of the building are two wings on the left and right also. Between the approach right wing and the rear right wing is a lecture theatre. The rear right wing contains the students classes while the rear left wing contains the laboratories. Each of the wings and central core contains courtyardsto enhance ventilation, lighting and interaction spaces. The floors 1-3 are similar in configurations and spaces except that the reception area terminates on the ground floor and the theatre terminates after the first floor, while floors 4 and 5 consists only the central core area and houses a kitchenette and lecture room(see figures 5.14, 5.15,, and 5.16).

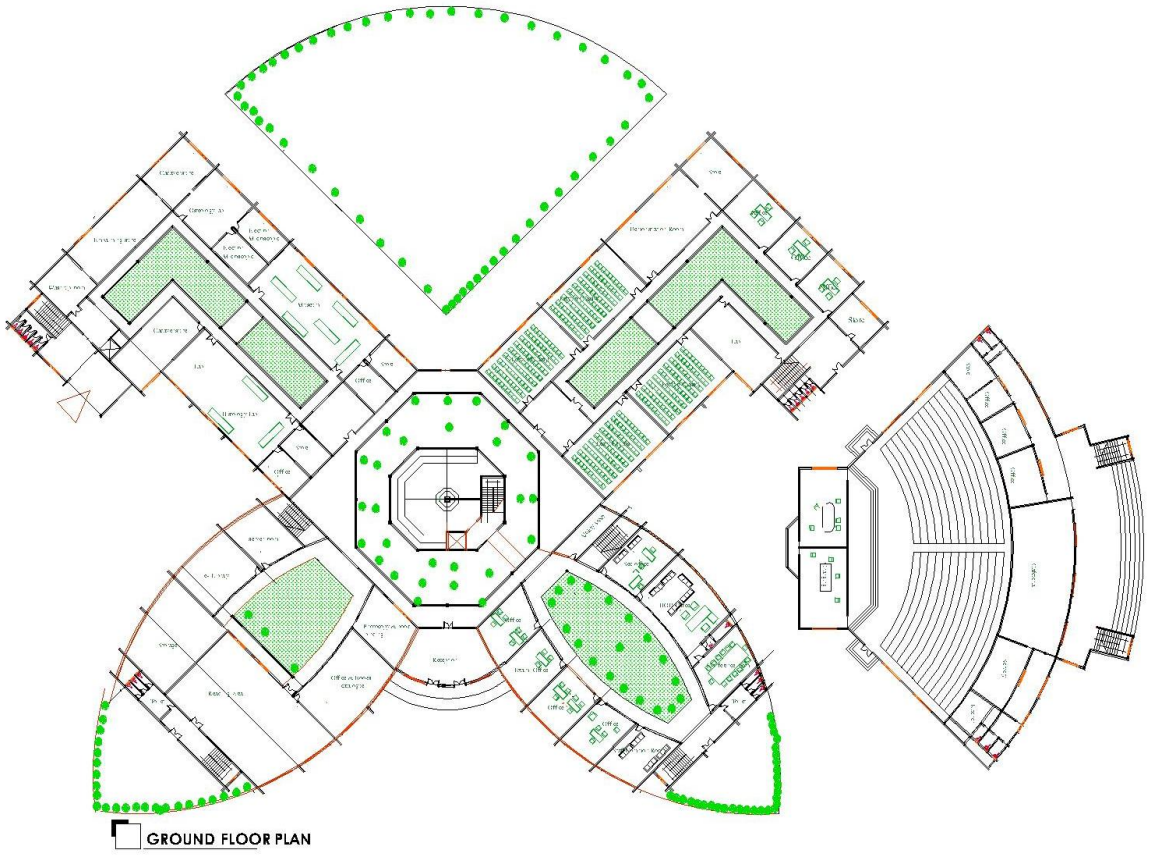


Figure 5.14:Ground floor of the proposed project.

Source: Author’s work

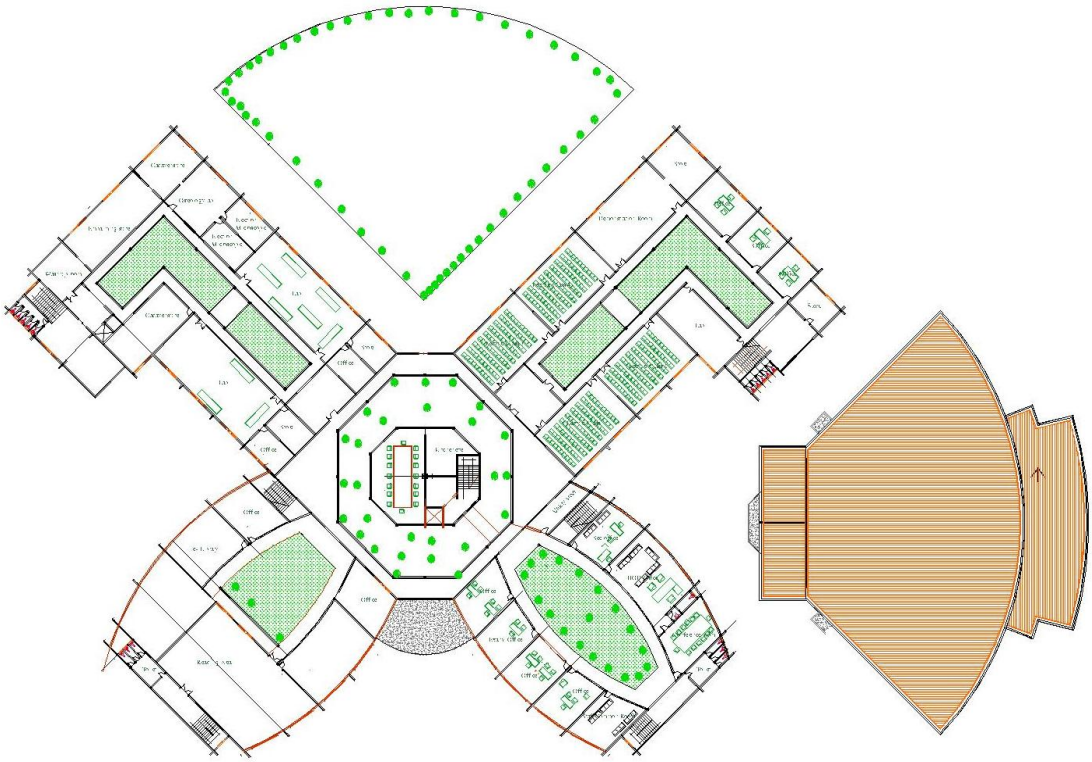


Figure 5.15:Floors 1-3 of the proposed project.

Source: Author’s work

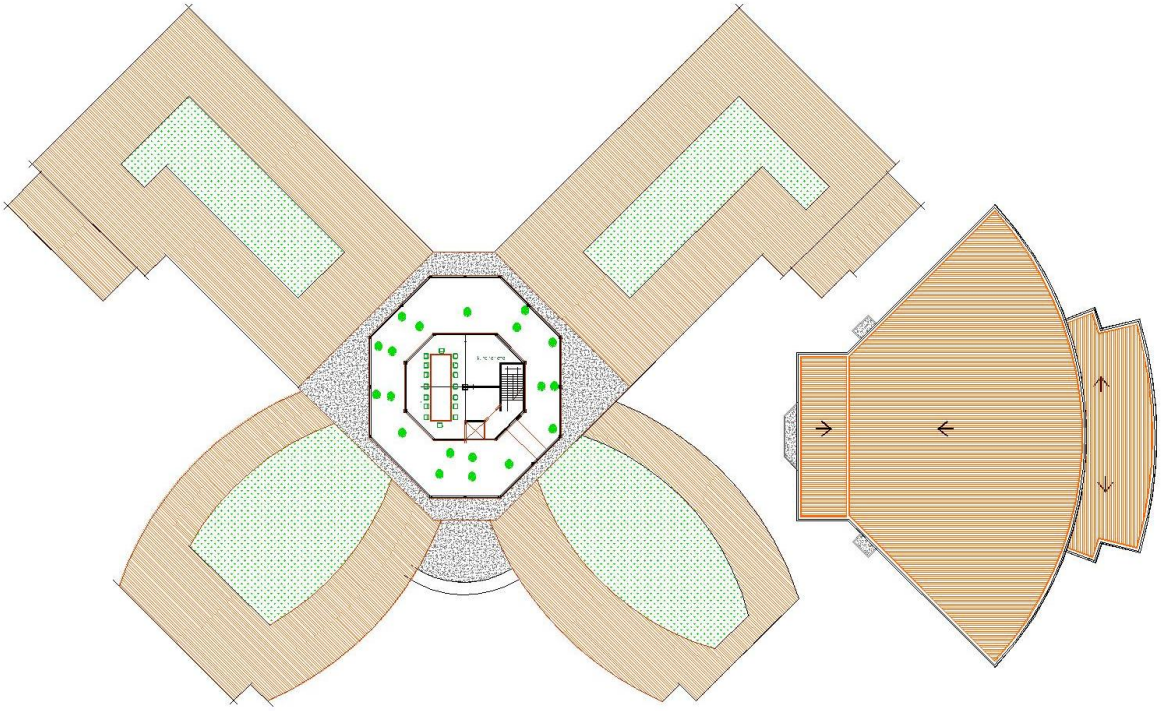


Figure 5.16:Floors 4-5 of the proposed project.

Source: Author's work

3. Elevations

The overall elevation is a five storey building, with the central core area going higher than the other floor levels. This gives it the outlook of a plant with the central core area being the flowering protruding from the plant and the leaves being the wings. The design employs the use of numerous energy management elements on the facades such as photo-voltaic and thastytronrastra panels, and also emphasized the connection between nature, and well-being (see figure 5.17).

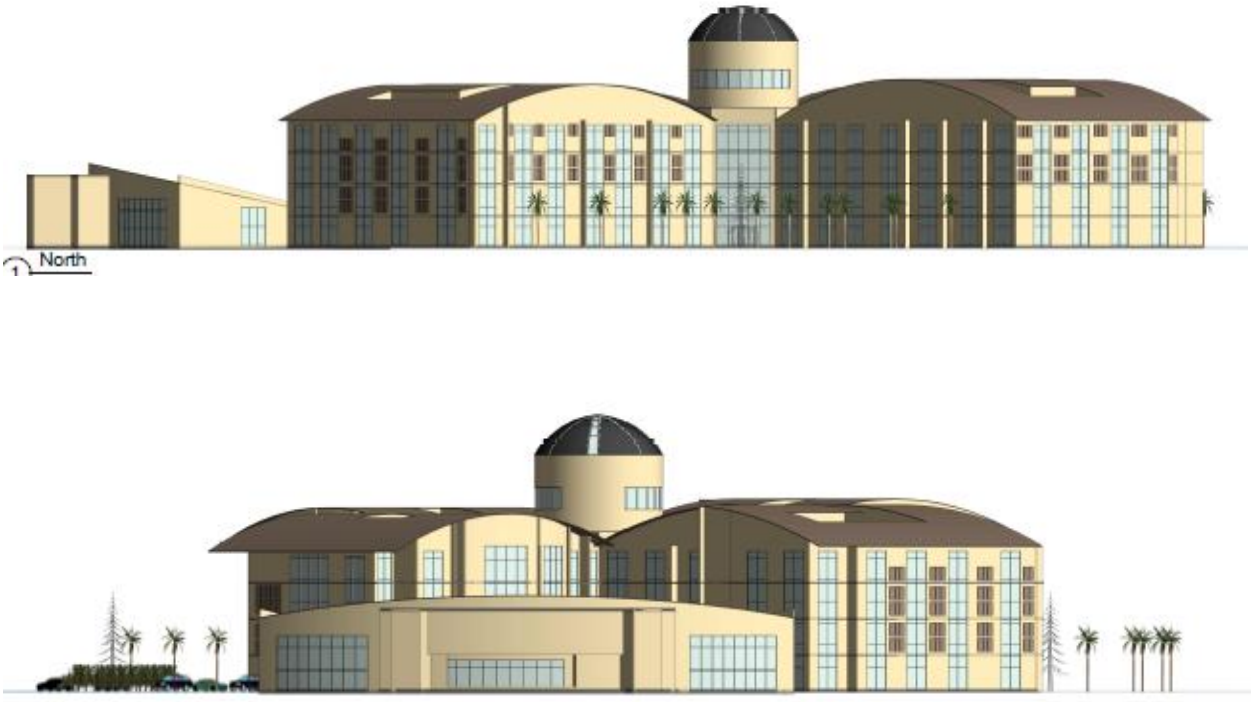


Figure 5.17:Elevational view of the proposed project.

Source: Author's work

5.9 CONSTRUCTION/MATERIALS

1. Construction Of Main Building

The plan as earlier discussed is a linear and curve form combined together to form a unique form. The building is suspended above the natural ground level 1.2 metres, with a normalpad foundation. The building is made of twoenvelopes the innermost core consisting of a more solid core. The outer envelope consists of a steel frame which goes round the building. This frame creates a medium that control solar radiation from the sun and also help to reduce the thermal insulation on the structure.The building has 5 courtyards, two in the admin area and one in the lecture classes' area. Centrally is a storey building independent of the main building is the Dean

office with board room attached and on the first floor a lecture theatre. Each floor having a height of 4.2 metres is connected via staircases and lifts. Waffle grid was used as flooring for all levels in the building. The use of extensive green roofs so as to help in thermal cooling of the building.The use of low level and high level windows so that stack effect is realized. An evident feature on the building is the presence of two atriums on the building.

2. Material

The innermost core consists of a solid core of cement/sand block, while the outer envelope consists of a steel frame which goes round the building glazed with fibre reinforced translucent ThastyronRatra panels on the north and south axis and translucent photovoltaic panels on the east and west axis. These panels have a very low thermal conductance and serve as a passive alternative power supply respectively. The steel envelope consists of two panels, having air trapped between these two frames. Only the outer frames have theses thastyronrastra panel sealing the frames. This is used to reduce thermal conductance at the same time sound insulation. These has at intervals on the steel frames, there are automated windows 300mm at the admin and laboratory building too. These windows open and close at intervals, the external walls are finished with panels and reflective paint, whereas the internal walls are finished with lotus white lotus inspired paint. The glass windows are of acrylic glass and doors are of steel.

The floors are finished with ceramic clay tiles in the offices, Carpet will be used in the board rooms, Terrazzo floor will be used in the lecture class and Lecture Theater and rough surfaced stone tiles in the laboratories. Plaster board suspended ceilings where used in all laboratories and offices inclusive.

CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 SUMMARY

The approach in this research was structured upon the premise that a truly biomimetic approach to architectural design requires the development of novel design methods that integrate both the modelling of natural forms and the constraints of materialization processes, in addition to environmental factors and influences. This thesis has provided insights on the current energy challenges in Nigeria and the importance of optimal thermal comfort in an academic environment in the introductory chapter. Relevant literatures were studied on biomimicry and its application in current architectural designs, resulting in a set of design approaches.Case studies were further carried out to identified core determinants of medical school designs and established the basic principles of biomimicry as a means of safeguarding against deterioration of the ecology and providing economic viable means of energy generation.The researcher took into cognisance the sensitivity of the existing natural environment and the expectations of the students and staff which are fundamental to creating an academic environment that promotes learning and increases staff productivity in order to propose a paradigmatic solution.

6.2 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 studies, it showed that the design of buildings especially those of medical schools are not energy efficient in Nigeria and so results in high running cost of these facilities. hospitals take the format of what happens in the western world and so has little consideration of the local architecture and culture of the host community.

6.3 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 the faculty of medicine complex. Imitating biological processes has been found to provide solutions to man's built environment problems. Therefore, adopting biomimetic processes in our design will help deal with energy consumption challenges in our designs as has been shown by some existing examples.

6.4 CONTRIBUTION TO KNOWLEDGE

This thesis has contributed to knowledge by giving insights to the application of a biomimetic scheme in the design of an academic environment. It shows that biomimetic elements can and should be reflected in the design of a medical school. As the integration of biology and architecture would serve as a systematic and effective way to harness natural energy sources for optimal thermal comfort of students and staff of the proposed faculty of medicine.

REFERENCES

Alexander, C. (2004). Sustainability and morphogenesis: The birth of a living world Paper presented at the Schumacher LectureBristol. Retrieved October 23, 2008 from www.livingneighborhoods.org/clickagreement/clickagreementces.htm

Alison, J., Brayer, M., & Spiller, N. (2003). Future City: Experiment and Utopia in Architecture. London: Thames & Hudson.

Baldinger, P. (2006). Energy and Sustainable Tourism: Energy Supply and Use in Off-Grid Ecotourism Facilities. USAID EGAT/Energy Team.

Baumeister, D. (2007) *Biomimicry Presentation at the University of Washington College of Architecture*. Seattle, USA. 8 May.

Benyus, J. (1997). Innovation Inspired by Nature: Biomimicry, New York: Quill William Morrow.

Benyus, J. (2013). "Spreading the Meme: A Biomimicry Primer," in *Biomimicry Resource Handbook: A Seed Bank of Best Practices. Page 11*

Berkebile, B. (2007) Master Speaker Address. *Living Future Conference.*Seattle, WA.

Biomimicry Guild. (2007).*Biomimicry methodology*.Online from http://www.biomimicry.net/essent_resourc.html. Retrieved March 22, 2014

Biomimicry Guild. (2009). What is *Biomimicryguild*. Online from http://www.biomimicryguild.com._resource.html. Retrieved March 27, 2014

Building Technical Manual, (1996).Green building design, construction and operation. From www.greenbuilding.com

Faludi, J. (2005) Biomimicry for Green Design (A How To).*World Changing*.

Famade, O.A., Omiyale, G.T., Adebola, Y.A. (2015). Towards Improved Funding Of Tertiary Institutions In Nigeria.*Asian Journal of Humanities and Social Sciences (AJHSS) Volume 3, Issue—2,*

Governor's Green Government Council, (2007). What is green building? Online from http/www.gggc.state.pa.us/gggc

Helms, M., Swaroop, S. V., &Goel, A. K. (2009).Biologically inspired design: process and products.*Elsevier*, 606-622.

Kellert, S. R., Heerwagen, J., &Mador, M. (2008). *Biophilicdesign :The theory,science, and practice of bringing buildings to life*. Hoboken, N.J.: Wiley.

Kelsey, S. (2010). Designing Medical Schools for the future.In health care design manual.

Kennedy, B.E., Lippens, D.F., Hsiung, B.K., Niewiarowski, P.H., Kolodziej, M.E., (2015).Biomimicry: A Path to Sustainable Innovation.

Knippers, J. (2009). Building & Construction as a Potential Field for the Application of Modern Biomimetic Principles.*International Biona Symposium.*Stuttgart:

Klein, L. (2009). A Phenomenological Interpretation of Biomimicry and its potential value for sustainable design.From anzasca.net/wp-content/uploads/2015/12/anzasca_2009_klein pdf. Retrieved 07 january,2016.

Livingstone, H. (2008). Looking to nature for the answer: HOK and biomimicry guild ally to create natural systems.Building solutions.AIA.From www.aia.org/architects/thisweek.Retrieved 8th November, 2012.

McDonough, W., &Braungart, M. (2002).*Cradle to Cradle-Remaking the Way We Make Things.* New York: North Point Press.

McLennan, J. (2004) The Living Building. Biomimicry in Architecture, Integrating Technology withNature.*BioInspire 18.S'*

McLennan, J., and Berkebile, B. (2004). The Philosophy of Sustainable Design: The future of architecture. Kansas City, MO: Ecotone.

Mumford, L. (2006). *guidelines for indoor thermal comfort & ventilation* retrieved February 18, 2012 from @http://www.usyd.edu.au/ohs/policies/ohs/IndoorThermalComfort.

Oyedepo, S.O, Adekeye T., Leramo, R.O., Kilanko, O., Babalola, O.P, Balogun, A.O. and Akhibi M.O. (2015).A Study on Energy Demand and Consumption in Covenant University, Ota, Nigeria.From the proceedings of the International Conference on African Development Issues (CU-ICADI).

Panchuk, N. (2006). *An Exploration into Biomimicry and its Application in Digital & Parametric [Architectural]Design***:** Master's thesis, University of Waterloo, Ontario, Canada, 2006. Retrieved from http://etd.uwaterloo.ca/etd/ntpanchu2006.pdf.

Reed, B. (2006) Shifting our Mental Model - "Sustainability" to Regeneration. *Rethinking Sustainable Construction 2006: Next Generation Green Buildings.*Sarasota, Florida.

Reed, B.(2011) Regenerative Development and Design Working with the Whole – published in Kibert, Charles book of Sustainable Construction, University of Florida.

Regenerative Leadership Institute. (2015). What is environmental design? From www.regenerative-leadership-institute.com.

Ruys, T. (Ed.) (1990).A Handbook of Facilities Planning, Volume 1: Laboratory Facilities
New York: Van Nostrand Reinhold.

Saleem, A.A., Abel-Rahman A.K., Ali A.H.H, Ookawara S. (2016). An analysis of thermal comfort and energy consumption within public primary schools in Egypt. *Journal of Sustainability, energy and the environment. 3 (1): 51-64.*

Thompson, D.W. (1917). Growth and Form. Cambridge university press.

U.S. Department Of Energy, (2010).Strategic Sustainability Performance Plan.A report to the white house council on environmental quality and office of management and budget. Online from www.energy.gov./2010/.doc. Retrieved 07 january, 2016.

Vincent, J. F. V., Bogatyrev, O., Pahl, A.-K., Bogatyrev, N. R. & Bowyer, A. (2005) Putting Biology into TRIZ: ADatabase of Biological Effects. *Creativity and Innovation Management*, 14**,** 66-72.

Vincent, J. F. V., Bogatyrev, O. A., Bogatyrev, N. R., Bowyer, A. &Pahl, A.-K. (2006) Biomimetics - its practice and theory.*Journal of the Royal Society Interface.*

Vogel, S. (1998).*Cat's paws and Catapults.Mechanical worlds of nature and people.*1st Edition. New York: W.W. Norton & Company.

Zari, P.M,(2007). Biomimetic Approaches to Architectural Design for Increased Sustainability. SB07 New Zealand, Paper number 033.

World Health Organization, (2014).A Modern Energy Services for Health Facilities in Resourced Constrained Settings; a renewal of status, significance, challenges and measurement.

www.arch.mcgill.ca/schemp, 2010.

www.climatedata.org, 2015.

www.inhabitat.com/eastgate center, 2015.

www.grimshaw-architects.com, 2015.

Maps.google.com.ng

www.skyscrapper-city.com