Biomimicry as a Tool for Creating Energy-Saving Facades

Sneha Jalindar Gangarde, Ar.Purva A. Kulkarni
DR. D.Y. Patil College of Architecture, Akurdi, Pune, IndiaEmail:
gangardesneha248@gmail.com
Purvakul10@gmail.com

Abstract: Since nature possesses complicated mechanisms that are developed over thousands of years, man has frequently drawn inspiration from it to resolve difficulties. Natural processes, on the opposite hand, symbolize sustainability values; yet, there are several lessons to be learned from nature so as to beat design difficulties and construct a more sustainable future. This promise is maintained employing a biomimetic design process. Bio-design could be a form of design that includes natural elements. Natural processes can aid within the implementation of essential energy-saving principles in design, like requirements, shape and energy performance, and development considerations. This study analyses cutting-edge design concepts, materials, and styles in building façades from the perspectives of biomimetics and bio-design. the planning principles are initially discussed, followed by the materials and some examples. Biomimicry and bio-design are aligned with the philosophy of energy efficiency; nevertheless, biomimetic notions must be at the forefront of the look to provide energy-efficient façade solutions.

Key words – Biomimicry in architecture, building skin, energy efficiency, façade development

INTRODUCTION

Biomimicry features a long history, dating back to 500 B.C., when Greek thinkers saw natural organisms as models for achieving a harmonic balance and proportion between thecomponents of a design that's synonymous with the classical ideal of beauty. Later, in 1482, Leonardo applied scientist was inspired by birds to form a flying contraption, which is taken into account the primary example of Biomimicry. It aided within the creation of the Wright brother's first aero plane prototype in 1948. Bionics was coined by Jack E. Steele in 1958, and he described it as "the science of natural systems or their equivalents.". The word Biomimicry, on the opposite hand, was coined in 1982. Janine Benyus, a scientist andauthor, popularized the word in her book "Biomimicry: Innovation Inspired by Nature" in 1997.

Biomimicry Definitions: Many researchers have attempted to define Biomimicry. Biomimicry, for example, is "a new field that examines nature's greatest ideas and then imitatesthe designs and processes to address human issues," accordingto Benyus. Architects confront a barrier, according toPederson Zari, in the lack of a clear definition from the many alternatives available to them in their projects. As a result, it's critical to assess the best way for completely implementing the best Biomimicry method and maximizing the benefits.Biomimicry, on the other hand, is described as "the study of overlapping disciplines of biology and architecture that reveal inventive possibilities for architectural issues," according to Guber.

Levels of Biomimicry: When tackling a design challenge, there are three major degrees of Biomimicry that will be used. Form, process, and ecosystem are samples of these. an answeris found in nature by examining the organism or ecosystem, shape, and process. It's crucial to work out which a part of biology is being replicated for this application. this can be noted as levelling.

Aim: -

To investigate the impact of biomimicry on the designof energy-efficient facades.

Objectives: -

a. To get a better understanding of biomimicry and how it might be used in the development of façades and building skins.

b. To investigate the impact of biomimicry and its material and building approaches on new technology.

c.Through the investigation of functional examples, determine if biomimicry might inspire energy-efficient building façades.

Scope: -

The goal of this study is to work out how biomimicrymight affect architecture in terms of façade development. the employment of biomimicry-based methodologies within the development of façades. Examining many components of the façade, like the thermal envelope, HVAC use, source of illumination, and electrical consumption, within the context ofbiomimetic design. Development of biomimicry shape, material, building method, and process, similarly as their function.

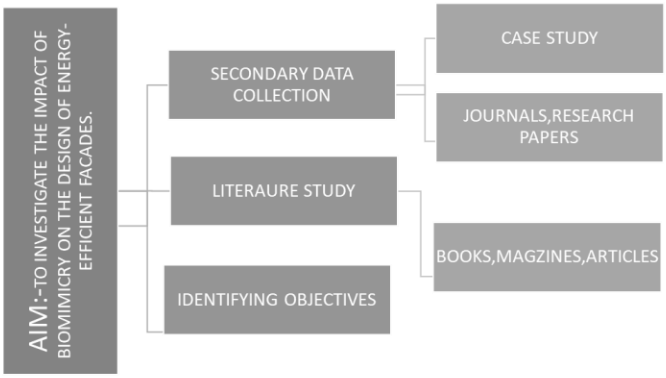
Limitations: -

Only the behavior level of biomimicry for façade creation will be studied in this project. The research will concentrate on both static and dynamic facades.

Hypothesis: -

Biomimicry has been used in a variety of sectors, including transportation, the automobile industry, electronics, and textiles. Biomimicry study in biology can provide new technology improvements and contribute to advancements in a variety of disciplines. By applying biomimicry principles to building skin, biomimicry principles could provide a framework for enhancing building energyefficiency.

METHODOLOGY



The different types of facades used are:

1. Kinetic façade - One Ocean Pavilion (2010–2012) was created for an open international competition in conjunction with Expo Yeosu 2012 in South Korea. The building's fundamental concept and appeal can be attributed to its kinetic façade with fish-like qualities. Biomechanical studies haveshown that the perch of a bird of paradise flower may be released more than 3000 times without showing signs of weariness. The One Ocean building's kinetic façade is made up of 108 fiberglass lamellas made of glass fiber-reinforced polymers that open and close with the help of a servomotor. Inorder to deploy into a doubly curved shape, the GFRP wings undergo lateral-torsional buckling.

Figure- 1 Bird of paradise flower

Figure- 2 The kinetic façade and closed lamellas

2. Smog-eating façades - Photocatalytic TiO2 in Italcementi cement has been identified as a smog-eating substance in recent years. When UV rays strike the tiles, a reactionhappens that converts mono-nitrogen oxides (the moleculesthat cause smog to be smokey) into less toxic substances likecalcium nitrate and water, as well as some CO2. This novelformulation was used on the facades of two modern buildings in Mexico City. The Italian Pavilion at Expo 2015 wasdesigned by the Italian architectural firm Nemesi and Partners(Figure 15). The six-story, 13,000-square-meter structure depicts Italy's past, present, and future through images,dynamic digital projections on mirrored walls, ceilings, and floors, and pulsating rhythms.

Figure- 3 Façade of Torre de Especialidades

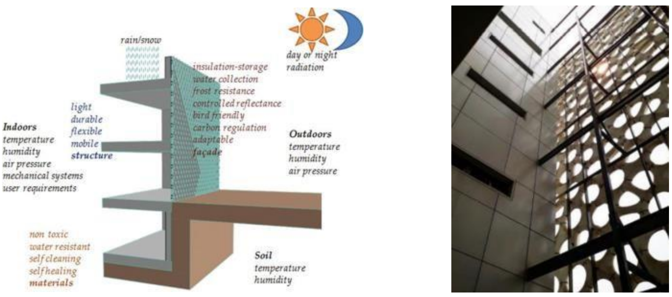


Figure- 4 Design principles of a sustainable façade

3. Cultivating algae - Algae are cellular creatures that were the forerunners of plants. They are more efficient at photosynthesis than many plant species. The algae façade acts as a barrier between the indoors and the outdoors, supplying thermal heating as well as biomass to the building. Köktürk et al. created an algae-based photobioreactor façade. It generates renewable energy and provides shade to keep the inside of the building cooler on bright days; it also gives a visually appealing appearance that architects and building owners will appreciate.

Figure-5 Facade of the Italian Pavilion in Expo 2015

Figure-6 BIQ Apartment House: (left) exterior &(right) closer view ofpanels

LITERATURE REVIEW

1. Adaptive biomimetic facades: Enhancing energy efficiency of highly glazed buildings

Author: Wajiha Tariq Sheikh, Quratulain Asghar,

Publisher: School of Architecture and Design,
University of Engineering and Technology, Lahore,
Pakistan.

Review:

In this article, they look at how to design an adaptive biomimetic façade as a realistic way to improve the energy efficiency of highly glazed buildings in hot and humid climates. They describe an adaptive façade that lowers solar heat intake and, as a result, the building's energy consumption while preserving the users' visual comfort (i.e., inside lighting levels and visibility to the outside environment). The façade's fundamental module is made up of four shading devices that can be folded in both horizontal and vertical directions. The design allows for shade in both high and low solar angles while maintaining visibility to the outdoors. To create the facade, they studied and imitated the physical, physiological, and adaptive qualities of an Oxalis oregana leaf, which has the ability to track the sun's passage and adjust its angle/position accordingly. They use an existing 20-story office building inthe hot and humid atmosphere of Lahore, Pakistan, as a case study for the suggested facade. The building's present energy load is reduced by 32% after retrofitting the intended facade, according to their numerical results. Furthermore, illumination levels within the required range of 500e750 lux are still present in 50% of the interior space (as opposed to 55% before to the retrofitting). The research shows that the proposed biomimetic facade can dramatically cut energy consumption in heavily glazed buildings while reducing visual comfort to a minimum.

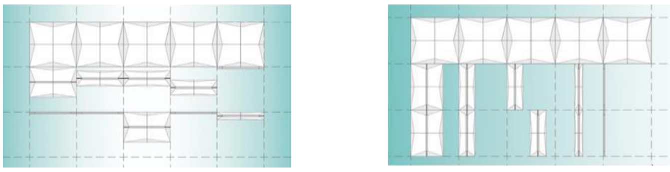


Figure-7 Folding of the proposed module into horizontal and verticleshading position.

2. Designing a facade by biomimicry science to effectively control natural light in buildings (Glare analysis)

Author: Sukhum Sankaewthong*1a, Teerayut Horanont1,Kazunori miyata2 and Jessada
Karnjana3

Publisher: 1.School of Information, Computer and Communication Technology, Sirindhorn
International Institute of Technology, Thammasat University, Thailand

Review:

The growing popularity of glass facades that use daylight in buildings has necessitated the development of new technologies to reduce the amount of light that enters areas unnecessarily. This research tries to create a kinetic façade design by using Wallacei evolutionary software to generate various patterns based on DNA structure and photosynthetic performance to replicate biomimicry science characteristics. Daylight glare tolerances were found to be an important element in user productivity. For preparing sites (zones A, B) in Bangkok, a comparison of three building envelope potentials was made: without a façade, with a static facade, and with a kinetic façade. The DIVA programme was used to assess glare in terms of the likelihood of daylight glare (DGP). First, the DGP (without façade) for zones A and B was 100% and 55%, respectively, indicating excessive glare.Second, the DGP (static façade) for zones A and B was 59 percent and 30 percent, respectively, indicating that zone A was intolerable and zone B was undetectable. Finally, the DGP (kinetic façade) for zones A and B was 28%. (Imperceptible glare). As a result, a kinetic façade has a significant potential for reducing unwanted glare. These findings could be used as a starting point for better understanding kinetic façade potential for self-adjustment by light intensity to improve occupant space utilization quality of life.

3. Skin in architecture: towards bioinspired facades

Author: P. Gruber1,2,3 & S. Gosztonyi4

Publisher: 1.Transarch – Office for Biomimetics and Transdisciplinary Architecture,
Austria Review:
This paper focuses on a shared parallel between biological skins and technology facades that was examined in student projects at the TU and is now being pushed further in the AIT-led programmed Bio Skin (Austrian Institute of Technology). The architectural character of a building isdefined by its facade, which is in charge of energy and information interaction with the surroundings. Facades as skins and bodyshells of creatures provide a catalogue of tasks that are only partially met by traditional facade technologies, allowing for novel, creative solutions. Skins and body shells serve as separating and linking structuresthat shield, limit, and contain living processes from a chaotic environment. The foundation for future research aimed at energy efficiency and sustainability is a compilation of existing projects and studies leading to a biomimetic building facade. Various design studies are shown that transfer characteristics of natural skins to façade systems and materials, as well as an introductory to Bio Skin project research that focuses on natural models for the architectural facade of the future.

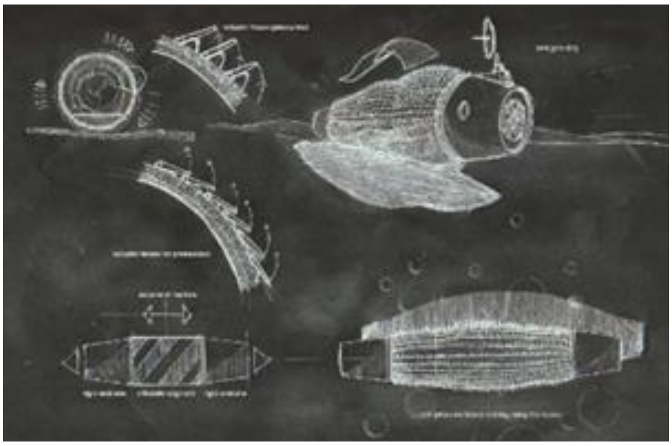


Figure-8 Rolling habitat for planetary exploration with a super adhesivesurface to generate radiation shielding

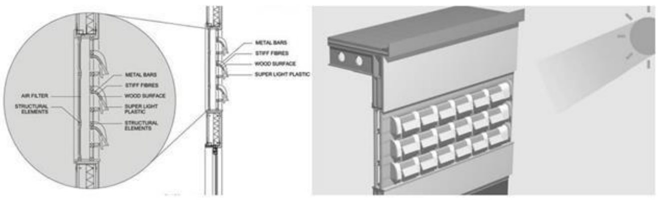


Figure-9 Ventilation openings using a pine cone mechanism

CASE STUDY

1. The Council House 2, Melbourne CH2: -

(CH2) could be a ten-story sustainable structure located in Melbourne, Australia. it had been constructed between 2004 and 2006, and it had been designed by the town of Melbourne together with Mick Pearce in design Inc. The structure's design was highly creative since it questioned establishedmethods to sustainability and architectural design by mimicking the bark of a tree. Design to biology was a biomimicry method. The building contains a 6-star greenrating. It absolutely was centered on connecting the building to its exterior environment and live creatures surrounding itso as to attain the goals. As a result, it responds to its surroundings holistically.

The use of biomimicry was evident throughout the structure. The west facade, as an example, is that the tree's epidermis. ithad been inspired by how the outside climate would be moderated by the facade. The north and south facades were modelled just like the tree's bronchi. As illustrated in (figure a), these were used as wind pipes and allowed for air ducts on the surface of the CH2. The eastern core and facade, including the service core and toilets, were designed to look like tree bark (figure b). within the ventilated moist region areas beyond, the skin served as a protective barrier, filtering light and air. Finally, pebbles are accustomed create the overlapping strata of the facade. within the ventilated moist region areas beyond, the skin served as a protective barrier, filtering light and air. Finally, so as to connect the louvres,the overlapping layers of the facade are made with perforatedmetal with polycarbonate walling.

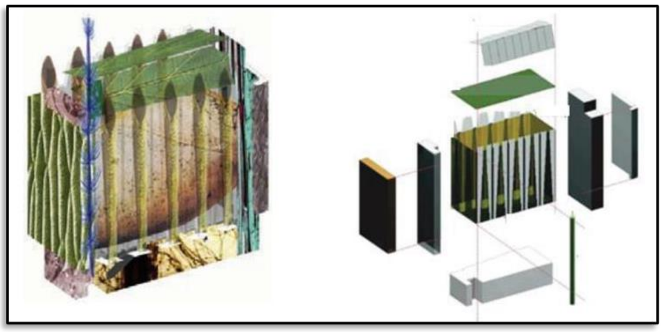


Figure-10 (a) wind pipes on the north façade (b) overlapping layers ofthe façade

Figure-11 Depicts a high-level view of the council house's overallproject. Façade

The design approach was beneficial since it resulted in the separation of typical industrial solutions. Despite the fact that future buildings may not look like the CH2, the CH2 symbolizes a living kind of architecture14. As a conclusion, it was decided that future structures should include the following features:

- Interact with the surroundings.
- Facades should express direction.
- Climate and culture should be expressed.

2. Water cube, Beijing: -

The Beijing National Aquatic Centre, commonly known as the water cube, was constructed between 2004 and 2007 primarily for the 2008 Olympic Games. Chriss Boss, Tristam Carfrae, PTW Architects, CSCEC, CCDL, and Arup designed the four-story structure. The Bio mimic was demonstrated in the structure by simulating the shape of soup bubbles, which also reflected the fundamental swimming ideal. Biomimicry is a design approach to biology.

The bubbles will steal the show, especially at night, when LEDs built into the pillow frames transform the Water Cube into a brilliant-colored box. The building's ability to alter fits in nicely with the design team's objectives: "Water cube has no fixed image," explains Wang. "It can either reflect the sky or have large waves."

Figure-12 Depicts a broad overview of the water cube's whole endeavor

The building skin has to be able to partition the spaces into equal-sized cells while still containing a little amount of surface area. At the same time, in order to be energy efficient, the building skin required to collect solar radiation. Tristan Carfrae, the water cube's creator, discovered that earlier scientists, such as Lord Kelvin, established in the 19th century that the tetrakaidekahedron allows a space to be split into equal-sized cells with the least amount of surface area between them. Plateau, a Belgian scientist, has studied soap bubbles and the principles that govern how they connect three faces together to form a line. The soap layers in the bubbles might diminish surface area and surface energy. Because the surface tension of the partitions lowers the surface area of the bubbles, this coincidentally solved Kelvin's query. The most economical technique to split a space turned out to be geometry.

Figure-13 Beijing National Aquatics Centre 'Water Cube' constructionmodel

As a result, the strategy was to view the foam array in a certain orientation before removing the foam block to acquire the structure's geometry. It is built around a repeating unit thatis tiled in 3D space, rotated, and then sliced across the axes to produce the geometric form seen in [figure c]. Even thoughthe geometric structure is very regular, it seems entirely random and organic when viewed from a specific perspective. As a consequence, it engages people both inside and outsideof the building to feel water.

Figure-14 Illustrates the Water Cube's geometric form.

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 07 | July - 2023 SJIF Rating: 8.176 ISSN: 2582-3930

The Water Cube was designed using biomimicry to find a geometric form that maximized surface area in a three- dimensional environment while being energy efficient. There were several biomimicry lessons learnt in this work, including:

- Nature's experience in the context of the environment
- Facades should convey a sense of direction.
- Creating a receptive and welcoming atmosphere
- Geometry and spontaneous form creation areextremely important.

3. The Esplanade Theatre, Marina Bay: -

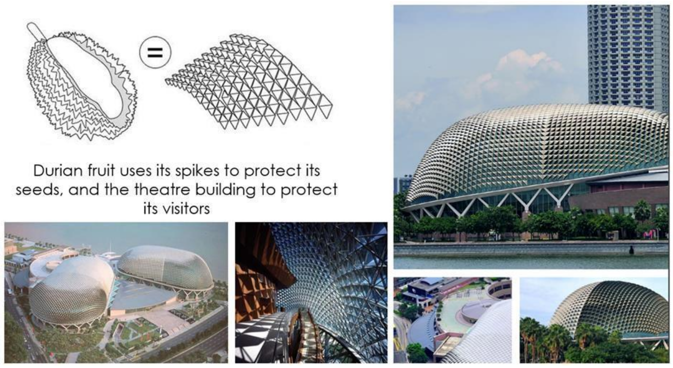
The structure is a two-story structure built by DP architects, Micheal Wilford. The Esplanade Theatre is located near the historic Singapore River in Marina Bay. After the first designwas criticized for including too much glass and being too Western, the decision to employ a Bio mimic approach was made.

The design was also chastised for being disrespectful to Singapore's tropical environment. As a result, the new design sought to create a structure that reacts to its surroundings and culture while remaining traditional. The building skin, which is inspired on the biology of the tropical durian fruit, is one- of-a-kind in that it offers shade and repetition in the face of the scorching temperature, borrowing inspiration from nature. The structure was built in 2007 and uses a biomimicry approach to design.

Figure-15 Depicts a broad overview of the Esplanade Theatre.

Sun shades were inspired by the spikes on the durian fruit to avoid overexposure to the sun in order to alleviate public concerns. The spikes, like the Esplanade theatre's sunshields, function as a protective covering for the fruit. Sunshields made of aluminum are built into each shell. The form is representative of traditional Asian culture and provides a sense of serenity. The sunshades on the east and west façade,

which get the most sun and heat, are the longest. The north and south facades, on the other hand, were significantly smaller4. The theatre is made of steel. Both the interior and exterior layers are connected by an internal grid and bracing system.



Natural materials such as wood and stone were employed in various parts of the theatre. The majority of the floors are stone-paved. Sandstone cladding is also used on the inside walls. The triangle shades are composed of insulating glass with aluminum fittings at the corners.

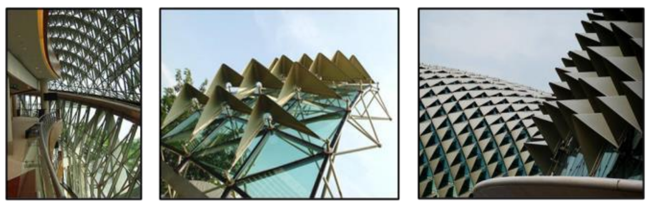
The theatre has a number of environmental consequences. The building's dynamic sun shield made it a landmark, and itsbio mimic influence gave it a distinct Singaporean identity. At the same time, the biomimicry method addressed the difficulties that had been expressed by the public1.

The application of biomimicry permitted the following: The following are some of the outcomes:

- Users will feel at ease in this atmosphere.
- Protection against the sweltering heat of Singapore.
- Allows natural light to penetrate while shielding the room from excessive heat.
- HVAC usage was reduced. Many of the lessons acquired, such as the use of biomimicry, were used to tackle the primary challenges that arose throughout the design process.

The application of biomimicry permitted the following:

- Added a feeling of culture to the structure.
- Geometry and patterns are used.
- Use of a sun path to offer protection in locations where it is needed.



Case Study	Concept and biomimetic level	Objectives	Reasons for choosing the analogy	Building Skin Material	Building skin outcomes
The Council House 2, Melbourne 	**Concept:** Tree **Level:** Organism and Behavior 	Environmental project including a lighthouse Greenhouse gas neutrality -Efficient in terms of energy -Improve one's health -Attend to the environment -Sustainable.	-The use of integral solutions -Model for complicated issues that works -Trees have a protective skin that produces a louvre system. -Trees are extremely energy efficient. -Trees moderate the external climate.	All Recycled -Timber -Steel -Concrete	-The air is completely filtered. -Around 65 percent of natural daylight and ventilation was conserved. -Makes the most of natural ventilation -Works in harmony with the natural world -Shading for a more pleasant visual experience
The Water Cube, Beijing 	**Concept:** Water bubbles **Level:** Organism 	-Build a well-insulated green home -Efficiency in terms of energy -Natural light entry -Isolation of the interior and outside environments	-Utilization of geometric shapes and patterns -Reduced surface area due to surface tension of bubbles -Created the illusion of water transparency	-Steel -ETFE sheets	-A 30% reduction in energy use -A 55 percent decrease in artificial illumination -ETFE helped the environment by conserving energy.
The Esplanade Theatre, Singapore 	**Concept:** The Durian Fruit **Level:** Organism and Behavior 	-Climate change considerations. -Follow the sun's path on the figure. -Developing a shading scheme. -Efficiency in the use of energy. -The significance of the place.	-Use of geometric shapes and forms. -Heat protection of spikes. -Durians' design allows for the best view of the bay.	-Aluminum -Insulated -Glass Steel	-User comfort -Heat protection -Natural illumination -Lower air conditioning levels.

CONCLUSION

For billions of years, nature has been self-sustaining and energy efficient. In order to be energy efficient, natural species have evolved and created ways. Human problems can be handled by incorporating these elements into architecture. In order to achieve a new technique for energy efficient building envelopes, mimicking nature has enormous potential. A large quantity of energy is used in the building envelope. Using the biomimicry technique, it is possible to reduce energy use by identifying and mimicking natural strategies.

ACKNOWLEDGEMENT

I would like to express my deep sense of gratitude from the bottom of my heart to my guide Prof. Purva Kulkarni for her valuable guidance, inspiration and encouragement. Her keen and indefatigable indulgence in this work helped me to reach an irreproachable destination.

REFERENCES

1. Asian building and construction, 2001. Esplanadetheatres on the bay. Singapore: DP Architects
2. Benyus, J.M., 1998. Biomimicry: Innovation Inspiredby Nature. Perennial (Harper Collins.)
3. Biomimicry Institute., 2011. Ask Nature. Retrievedfrom http://www.asknature.org/article/view/what_is_ask_nature
4. Bar-Cohen Y., 2005 (Ed.), "Biomimetics: Mimickingand being Inspired by Biology," CRC Press, pp. 505
5. Kieran, S. & Timberlake, J, 2004. RefabricatingArchitecture. New York: McGraw-Hill.
6. Mazzoleni, I., 2013. Architecture follows nature- Biomimetic Principles for Innovative Design. CRC Press.
7. Steadman, P. 2008. The Evolution of Designs- biological Anology in Architecture & Applied Arts. Oxon: Routledge
8. Zari, M.P. 2007. Biomimetic Approaches to Architectural Design for Increased Sustainability. Sustainable Building Confernece. Auckland