"Biomimicry" Innovative Approach in Interior Design for Increased Sustainability

Dr. Inas Hosny Ibrahim Anous
Lecturer/Department of Interior Design and Furniture
Faculty of Applied Arts / Helwan University
Arab Republic of Egypt

Abstract: The relationship between architecture and nature is one that has brought many questions. Biomimicry is taking the philosophy behind natures living organisms and uses them to aid in the development of mankind. The application of Biomimicry is wide: By mimicking a variety of elements from nature, the final composition will not only respond to the activities within the building, but also to the surrounding environment. Biomimicry is a path for a sustainable future. The paper gives an overview of Biomimicry, its approaches and levels of applications in interior design. The analyses shows that using biomimicry as a problem solving methodology will help us discover sustainable and effective solutions to the most important issues in the interior environments: day lighting, thermal comfort, energy efficiency, durability, and productivity.

Keywords: biomimicry, sustainable building, bio-inspired design, Biomimicry Interior Design, Biomimicry - Sustainable Design.

I. Introduction

"The best way to predict the future is to design it"[1]. Humans have learned much from nature. Nature has always inspired human achievements and has led to effective materials, structures, processes and the results have helped surviving generations and continue to secure a sustainable future. The field of Biomimicry where flora, fauna or entire ecosystems are emulated as a basis for design, is becoming an increasingly well-known topic and has attracted worldwide interest in the fields of design, engineering, architecture, and business, imitating nature’s designs and processes to solve human problems [2], [3]. The inspiration from nature is driving force in architecture, resulting in majestic works of architecture. For any sustainable building design, need to consider structural efficiency, water efficiency, zero-waste systems, thermal environment, and energy supply; Biomimicry is an alternative solution. Biomimicry is a new way of viewing and valuing nature, based on what we can extract from the natural world, but what we can learn from it [4] Designers draw their inspiration from multiple sources to address challenging design problems. One method is to study nature, and attempt to comprehend the ways in which it has evolved to address environmental challenges [5].

II. Research problem

The lack of a clearly defined approach to Biomimicry that interior designers can initially employ, particularly if the goal is to increase the sustainability of the built environment. Interior design uses biology as a library of shapes alone as biomimetics without some biology in it.

III. Research objectives

Exploring the potential of biomimicry in architecture and interior design. Exploring the application of Biomimicry in current architectural design, resulting in a set of design approaches, levels and principles. Study how to Achieve a sustainable environment with radical increase in resource efficiency by looking to the nature for inspiration" biomimicry". Raise the awareness of interior design students about ‘nature’, ‘sustainability’ and ‘nature inspired design approaches’. Creating a community that will scale the practice of biomimicry and the idea that nature's wisdom is a powerful natural resource we have yet to fully explore.

IV. Methodology

The paper is divided into five sections: the first gives an overview about Biomimicry. The second explains the relationship between Biomimicry and Nature. The third section discuss the Design approaches and levels of Biomimicry and its design methodology. The last section analyses the Applications of biomimicry in interior design and furniture. The researcher follow the inductive approach through access to the latest scientific literature related to the subject of research and the analytical approach by the analysis of some applications of Biomimicry in interior design.
V. Fundamentals concepts about biomimicry

A. Bionics
The term 'bionics' (biology + technics) describing the process of “copying, imitating, and learning from biology” was conceived by Jack Steele in as early as 1960 prior to the infamous Bionics Symposium[6].

B. Biomimetics
The term is as a derivative of Greek words "bios" meaning life and "mimesis" meaning imitate [6]. It represents the studies and imitation of nature’s methods, mechanisms and processes[7].

It was conceived by Otto H. Schmitt, one of the early giants in biomedical engineering, a founding president of Biomedical Engineering Society and founding vice president of the Biophysical Society, in approximately 1969[6]. Biomimetics is the replication of the functionality of a biological structure by approximately reproducing an essential feature of that structure[8].

C. Biomimicry
Janine Benyus defined the term ‘biomimicry’ as a "new science that provide innovative and sustainable solutions for industry and research Development ". Janine Benyus was known as the founder of the Biomimicry movement. She is a highly accredited biological sciences writer who has inspired and brought forth a new dimension to design by looking to nature as the key source of inspiration. For her Biomimicry is the conscious emulation of nature's genius"[9]. Biomimicry uses an ecological standard to judge the sustainability of our innovations[4].

C.1 Nature-inspired design strategies
Nature-inspired design strategies are design strategies that base a significant proportion of their theory on ‘learning from nature’ and regard nature as the paradigm of sustainability. Ingrid de Pauw, Prabhu Kandachar, Elvin Karana, David Peck, Renee Wever[10].

C.2 The philosophy behind Biomimicry
Biomimicry is a new discipline that studies nature's best ideas and then imitates these designs and processes to solve human problems[11]. It is a new type of ideology that combines biology and architecture in order to achieve complete unity between the building and nature. The Biomimicry approach based on studying the living organisms -their structures, functions, processes, interactions and relationships among them and their surroundings, in order to learn from their strategies, methods and principles and emulate them to optimize the environmental performance and attitude of the designs. Biomimicry is often described as a tool to increase the sustainability of human designed products, materials and the built environment [12].

C.3 Importance of Biomimicry research
Bio mimicry is considered to be one of the most important design tools that flourished with the dawn of the twenty first century to evolve revolutionary sustainable design solutions. Biomimicry is an approach to innovation that seeks sustainable solutions to human challenges by emulating nature's time-tested patterns and strategies.

VI. Biomimicry and Inspiration from nature

A. The evolution of mankind relationship with nature [1]

Fig. 1: shows diagram showing the evolution of the relationship of mankind with nature

A.1 Nature in Architecture of old civilizations
The old civilizations like the Egyptian Pharohs, old Greeks and Romans and Islamic civilization, simulate nature but also apply laws of nature in a scientific way in their designs "Fig 2". Their designs were: Harmonious with nature. Adapted with the natural environment. Commensurate with the privacy of the place. Use materials from the surrounding environment. Affected with the local environment in the shape, characteristics and performance. The environment was respectable [12].

Fig. 2: shows the difference between the pharaoh's house, Roman's house and Elsehimy Islamic house
A.2 The Bio mimicry Evolution Timeline

Our history is marked by numerous approaches to the solution of engineering problems based on solutions from nature. All of these approaches are progressions along the same line of thought: "Engineered Biomimicry", which encompasses bioinspiration, biomimetics, and bioreplication [8]. Since the creation of the human, the Raven learned the burial to Cain – who killed his brother. Primitive cultures and ancient civilizations simulate nature to find solutions to their daily needs; Egyptian civilization has inspired a lot of architectural elements (columns, furniture, decorations) from the forms and structures of local organisms. In 15 & 16th century; Leonardo Da Vinci (1452-1519); the first researcher in Bionics or Biomimetic mechanical engineering. He studied the formation and movement of bird’s wings, tried to simulate them and invented the flying machine. Mathew Baker (1590) was one of the leading designers of ships who inspired from nature how to build large ships structures. The design idea of the structure of the ship simulated head and tail of the mackerel fish. In the 18th century; John Smeaton (1759) who was a civil engineer. He used the form structure of oak trees as a basis in the designing of Eddystone lighthouse because of its hardness and durability. In the 19th century, The natural organic forms were the inspiring basic model for the architect Antoni Gaudí (1883). In La Sagrada Familia Cathedral in barcelonha he tried to simulate trunks and branches of trees and snails spiral and used them as Structural elements resist to wind and weather conditions and the transfer of loads not only in decoration. Gustave Eiffel (1889) who was a civil engineer, designed Eiffel tower. He simulated the upper part of Femur or Thigh bone as it Is the strongest bone in the human skeletal structure as it act as a carrier to what above it and a holder to the rest of the leg. In the 20th century; Frank Lloyd Wright (1956) took the organic architecture way. It is not only a simulation for natural objects but he uses the nature principles in a new way. Eugene Tsui (1980), an architect, industrial designer, scientist and inventor, stated that human and nature must become partners in the design to create a world of beauty. He invented new way of architecture called it Evolutionary Architecture. In [1997] The biologist and natural Sciences writer Janine Benyus is known as the founder of the Bio mimicry movement, she collected all her theories in a book called ‘Biomimicry: Innovations Inspired by Nature. In 1998, Janine and Dr. Dayna Baumeister founded The Bio mimicry Guild which uses a deep knowledge of biological adaptation of organisms to help designers, engineers, architects and business men to solve design and engineering problems in a sustainable manner. In 2005, Janine benyus founded The Biomimetic Institute. In 2008, The Biomimicry Portal Prototype is produced; it is the first a digital data base for biological organisms that have the strategies to solve problems commensurate with the humanitarian community [12].

B. Nature design principles

The nature's unique characteristics and principals that can be applied and help develop architecture and design is as follows: Nature runs on sunlight, Nature uses only the energy it needs, Energy fits form to function, Energy recycles everything, Nature rewards cooperation, Nature banks on diversity, Nature demands local expertise, Nature curbs excess from within, Nature taps the power of limits [13]. According to Benyus, ten principles can be identified as underlying nature’s rules for sustaining ecosystems: Use waste as a resource, diversify and cooperate to fully use the habitat, gather and use energy efficiently, optimize rather than maximize, use material sparingly, don’t foul nests, don’t draw down resources, remain in balance with the biosphere, run on information, shop locally. If our products, interior spaces, buildings and cities have designed in accordance with these principles, as Benyus suggests, we would be well on the way to living within the ecological limits of nature, and thus achieving our goal of sustainability [14]. Nature solves the following aspects The economy of constructive materials, Original structures, perfectly adapted to their environment, Aesthetic quality, Principles of nature provide verified information through the natural selection process, Nature is timeproof [15].

C. The way of thinking about nature:
Nature as model: Biomimicry studies nature’s perfect models takes inspiration from their designs and processes to solve human problems sustainably.
Nature as measure: Biomimicry uses an ecological standard to judge the ‘rightness’ of our innovations, according to nature's life principals
Nature as mentor: Finally, relationship with nature would change by Biomimicry, from seeing nature as a source of raw materials, to a source of ideas for problem solving, a mentor that has the wisdom and knowledge for survival and living sustainably [1].

VII. Applying Biomimicry in the interior design

A. Applying Biomimicry in the design process: Biomimicry Design Spiral

The Biomimicry Institute created a Design Spiral methodology as shown in "Fig 3" to help people learn and practice Biomimicry [16].
B. Design approaches of Biomimicry

B.1 Direct approach: Problem – based approach

This approach has different naming "Design looking to biology", "Top –Down Approach", "Problem –Driven Biologically Inspired Design". In this approach, designers look 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 [17].

B.2 Indirect approach: Solution- based approach

Identifying particular characteristics or behaviors in an organism or ecosystem and then translating that into human designs, "Fig 5" referred to as "biology influencing design Biomimicry", and "Bottom-Top Approach" [18].

C. Levels of Biomimicry

Three levels of Biomimicry determine which aspect of 'bio' can be 'mimicked' and applied to a design problem, the organism, the behavior and the ecosystem level "Fig 6". Within each of these levels, a further five possible mimic dimensions exist: (form), what it is made out of (material), how it is made (construction), how it works (process) or what it is able to do (function) "Fig 7" [1].

Fig. 3: shows the design spiral Methodology

Fig. 4. The steps of problem- based approach

Fig. 5. The steps of solution- based approach

Fig. 6. shows the levels of Biomimicry. Fig. (7) shows the five mimic dimensions
C.1 Organism level: The Minister of Municipal Affairs & Agriculture (MMAA) in Qatar:
The skin of one of the hardiest plants of the desert “Cactus” is applied to the design of the facade of a desert building, with hundreds of smart shades that open and close depending on the strength of the sun [19].

(a) Design problem:
Aesthetics Architects was looking for inspiration to design the (MMAA) in Qatar that would be situated in the hot, dry climate of Qatar, an area that only receives approximately 3.2 inches of rainfall annually “Fig 8”

(b) Biological solution:
They decided to investigate the Cactus for ideas on a building solution. Cactus, organism that has adapted to arid, dry climates and so unique in the technology it uses in order to survive. The signature characteristic of a cactus is the “spines” that serve more than just one purpose. The obvious purpose for the spines is for protection. It makes it very dangerous and difficult for herbivorous animals to eat the plant. They also serve to channel the rain water down to the base of the plant where it gets collected and stored. But the most important function that the spines serve is to help shade the plant from the intense sun, so the energy-efficient structure was designed by Aesthetics Architects.

(c) Design solution:
Architects designed the (MMAA) in Qatar using these technologies to create a unique sustainable solution to a complex problem. The botanic dome at the base of the tower will provide sustainable food source irrigated from Grey and black water treatment. In addition, they incorporate sunshades on the exterior of the building with the rain water down to the base of the plant where it gets collected and stored. But the most important function that the spines serve is to help shade the plant from the intense sun, so the energy-efficient structure was designed by Aesthetics Architects.

Fig. 8: Fig 8a shows the Cactus plant, Fig. 8b & Fig. 8c shows the exterior shades and Fig. 8d shows the interior of the building.

C.2 Behavior level: Eastgate tower in Zimbabwe

(a) Design problem
The architect Mick Pearce, was looking for inspiration to design the Eastgate center in Zimbabwe where the temperature outside can vary from 3 °C up to 43 °C and where the air conditioning plays a significant role “Fig 9”

(b) Biological solution:
Mick Pearce looked at "termites" which have an amazing ability to maintain virtually constant temperature and humidity in their termite mounds in Africa despite outside temperatures that may vary from 35°F to 104°F (3°C to 42°C). Researchers initially scanned a termite mound and created 3-D images of the mound structure, which revealed construction that can influence human building design [20]. The way they construct their mounds to maintain a constant temperature. The insects do this by constantly opening and closing vents throughout the mound to manage convection currents of air - cooler air is drawn in from open lower sections while hot air escapes through chimneys [21].

(c) Design solution:
The Eastgate Centre, a mid-rise office complex in Harare, Zimbabwe, uses a form of passive cooling similar to how the termite mound works. It was designed to mimic the heating and cooling systems that termites use in their mounds to Create Sustainable Buildings. The innovative building uses similar behavior in the design, and air circulation planning it stays cool without air conditioning and uses less than 10% of the energy used in similar sized conventional buildings, hence moving towards a more sustainable building [1]. His solution was to have specially designed hooded windows, variable thickness walls and light colored paints as a part of a passive-cooling structure to reduce heat absorption. By doing so Eastgate uses 90% less energy for ventilation than conventional building its size and has already saved the building owners over $3.5 million dollars in air conditioning costs [22].
Ecosystem Level: the construction of Earthships

(a) Design problem
Design an Earthships to integrate with nature.

(b) Biological solution:
Biomimicry design is not only adapting the design from the nature but also considering how to use nature’s effective functions such as heating and cooling system, protecting natural light and ventilation. So the solution is to investigate the natural design principles for ideas on a building solution to mimicking a specific ecosystem which elements and principles are required for it to function successfully "Fig 10".

(c) Design solution:
The Earthships are designed to integrate with nature based on six natural design principles:
1. Constructed with recycled and local materials: Tiers, sand bags, adobe….etc.
2. Heating and Cooling: From the sun and the earth.
3. Water Harvesting: Caught on the roof from rain and dew mimicking the Namibian beetle bumpy body.
4. Renewable Electricity: Photovoltaic / wind power system. This energy is stored in batteries and supplied to electrical automated outlets, including grid-intertie.
5. Sewage: Gray water from bathing, washing dishes is separated from black water from the toilet. The gray water, is used and filtered for a second time in interior botanical cells. The flush toilet is the third use of the water, which is contained, treated and used a fourth time in exterior botanical cells.
6. Food production: Food is grown inside with botanical planters and outside in landscape irrigated with treated gray water [1].

Fig.10: Fig. 10 a & 10b shows Earthships are sustainable homes made of recycled materials, designed to integrate with nature as an example of biomimicry in the Ecosystem level.

Fig. 10c: shows the interior botanical cell in Earthships. Fig. 10d: shows photovoltaic solar cells for renewable energy.
Fig. 10e: shows the Earthship interior bathroom design constructed with natural recyclable materials.

VIII. Applications of biomimicry in architecture, interior design and furniture

A. The Habitat 2020
The Habitat 2020 building envisioned for China "Fig 11" is a future forward example of biomimetic architecture that fuses high-tech ideas with basic cellular functions to create ‘living’ structures that operate like natural organisms. This nature-inspired approach to city living looks at the urban landscape as a dynamic and ever-
In this cityscape, buildings open, close, breathe and adapt according to their environment. The Habitat 2020 building radically alters perception of a structure’s surface. The exterior has been designed as a living skin, rather than a system of inert materials used only for construction and protection. The skin (Fig. 4) behaves like a membrane which serves as a connection between the exterior and interior of the habitat. Alternatively, the skin may be considered as the leaf surface having several stomata cellular openings involved in gaseous exchange and transpiration in plants. The surface would allow the entry of light, air and water into the housing. It would automatically position itself according to the sunlight and let in light. The air and wind would be channeled into the building and filtered to provide clean air and natural airconditioning. The active skin would be capable of rain water harvesting where water would be purified, filtered, used and recycled. The skin could even absorb moisture from the air. The waste produced would be converted into biogas energy that could be put to diverse uses in the habitat [11], [23].

**Fig.11: Habitat 2020, china and the Living skin of Habitat 2020**

### B. The Esplanade Theater

The Esplanade Theater and commercial district in Singapore, designed by DP Architects and Michael Wilford, hosts an elaborate building skin which influenced the look and function of the interiors, inspired by the multi-layered Durian plant with its formidable thorn-covered husk "Fig 12". The Durian plant uses its semi rigid pressurized skin to protect the seeds inside, just as the building exterior is part of an elaborate shading system that adjusts throughout the day to allow sunlight in but protects the interiors from overheating [20].

**Fig. 12: The Esplanade Theater and commercial district in Singapore**

### C. The Treepods: Carbon-Scrubbing Artificial Trees for Boston City Streets

One of the interesting examples of beneficial biomimicry are the Treepods designed by Influx Studio. The inspiration came from The most unique trees in the world, the Dragon Tree because of the large canopy that provides maximum shading which also allows the structure to support solar panels used to power the air cleaning system "Fig 13". These Treepods are not designed to replace natural trees, but to act like small air cleaning infrastructures, increasing in many times CO2 absorption [11]. The TREEPOD takes the Dragon tree like form to create an important canopy surface that will provide shadow, and that will host a solar pv (sun tracker latest technology) to harvest the energy necessary to powered the air cleaning system and the urban lamp function. The canopy branching structure ends with a myriad of bulbs. They multiplies the contact points between air and the CO2, serving as a filter. Working like as alveoli in a human lung, here is where the cleaning gaseous exchange takes place: an alkaline and environmentally friendly resin that reacts with air holding CO2[24].
D. Mimic The Lotus's flower in painting

The lotus flower's micro-rough surface naturally repels dust and dirt particles, keeping its petals sparkling clean. A German company, Ispo, spent four years researching this phenomenon and has developed a paint with similar properties. The micro-rough surface of the paint pushes away dust and dirt, diminishing the need to wash the outside of a house [25].

E. The honeycomb shape of beeswax in a bee hive

Through the process of creating blinds that were ergonomically able to diffuse and keep light out efficiently, designers and scientists adapted the shape and form of the honeybee's honeycomb to keep light contained and properly diffused 'Fig 14' [26].

F. Biomimetic approach to create concept chairs

F.1 The Bone Chair by Joris Laarman

In 2007, Joris Laarman of Amsterdam, Netherlands, explores the Form : one of the core methodologies (form, process, and system) of biomimetic design. Joris Laarman used SKO, a structure optimization algorithm that simulates bone mineralization, to design his innovative Bone Chair. Bone is a smart composite made of specialized cells and protein fibers. As strong as steel and as light as aluminum, it reacts to resist stresses from constantly changing external structural forces "Fig 14".

F.2 The Cellular Chair by Mathias Bengtsson

Mathias Bengtsson of London designed the Cellular Chair, in 2011, Designed and Made Based on the Natural Processes of Self-Organization "Fig 15". The design of the chair explores the process one of the core methodologies -form, process, and system- of biomimetic design: Based on the growth principles of human bones, composed of lightweight epoxy, the material is designed to simulate the regeneration of bone tissue [27].
IX. The future of biomimicry in the interior environment

Now, biomimicry is still in its infancy in the interior environment. It is expected that it will continue to be applied most wildly in architecture and interior environment in the future, particularly as a tool of sustainable design in terms of day lighting, energy consumption and ecological footprint of new facilities. The architectural and interior design profession are cohesive enough to allow innovative approaches and new technologies to spread rapidly particularly when the profit is clear. As an example, the ability to effectively provide daylight into an interior space that has limited access to it reduces the need for artificial lighting. As a result, less heat is generated and less cooling is necessary, which could reduce cooling equipment’s size (a capital cost). Overall energy use is reduced (a cost of operation), and the dependence on fossil energy is lessened (an environmental cost). This is in addition to the important aesthetic and human benefits that daylight offers. We can say that using biomimicry as problem solving methodology can help create a new sustainable standard for interior spaces, buildings, communities and cities worldwide. For architects and other design professionals, it opens up a whole new world of innovative ideas for transforming the interior environment, while optimizing human well-being. And beyond the projects themselves, the principles of biomimicry will help in providing design smarter, and connect the work with the natural environment. In the future, the interior spaces we live in and the workplace we work in might be designed to function like living organisms, specifically adapted to place and able to provide all of their needs for energy and water from the surrounding nature. The architecture and design will have inspiration, not from the machines of the 21st-century, but from the butterfly that flies in the sky or the flower that exists in the landscape that surrounds them.

X. BIOMIMICRY TO INCREASE SUSTAINABILITY

Biomimicry is often described as a tool to increase the sustainability of human designed products, materials and the built environment. It should be noted however that a lot of biomimetic technologies or materials are not inherently more sustainable than conventional equivalents and may not have been initially designed with such goals in mind. As discussed, most examples of biomimicry are organism biomimetic. While biomimicry at the organism level may be inspirational for its potential to produce novel architectural designs, the possibility exists that a building as part of a larger system, that is able to mimic natural processes and can function like an ecosystem in its creation, use and eventual end of life, has the potential to contribute to a built environment that goes beyond sustainability and starts to become regenerative. This does not prevent organism biomimicry at a detail or material level. A building that is exhibiting form biomimicry, which is stylistically or aesthetically based on an organism, but is made and functions in an otherwise conventional way, is unlikely to be more sustainable than a non-biomimetic building. A building that is able to mimic natural processes and can function like an ecosystem in its creation, use and eventual end of life has greater potential to be part of a regenerative built environment. Both buildings could be termed biomimetic, but the potential for increased sustainability would obviously be quite different. It is suggested that if biomimicry is to be conceived as a way to increase sustainability of an architectural project, mimicking of general ecosystem principles should be incorporated into the design at the earliest stage and used as an evaluative tool throughout the design process [18].

XI. Conclusion

1. Biomimicry which is a multi-disciplinary innovative tool involving a wide diversity of domains like electronics, biology, chemistry, physics design and engineering, studies nature and emulates its creative functions, processes and eco systems using advanced technology to solve human problems in integration with nature.

2. Biomimicry is studying the nature, learning from it and getting the most important principles and characteristics then apply it to solve a specific design problem. The main goal of bio mimicy is sustainability. 3. There is need for future young Architects and designers to Create bio-inspired design adaptations that emulate nature’s best ideas, so that all futuristic buildings will be sustainable.

XII. Recommendations

1. To the expansion of biomimetics, education must play a significant role. It should be included in the education syllabus of architecture and design degrees to make them aware of the potential of the approach. Networks, workshops and events could help forge links and transfer knowledge between the designers and the biologists.

2. Build a documented database, in a format of web-page hyperlinks, That would examine biology from an engineering point of view and to catalog nature capabilities including the inventions that have already been used to possibly offer different angles of looking at nature’s innovations to enrich other fields that have not benefited yet.

3. Cooperation between biologists and technologists/engineers as well as the establishment of such an education path in academic institutes that hopefully will also lead to new disciplines of biomimetic science and engineering.
4. Teach interior architects how to open their eyes to the genius of natural world in an attempt to inspire new paths for living sustainably on earth, therefore changing the evaluation criteria of future designs as well as approaching a different conscious definition and appreciation to nature.

References
[6] Iouguina, A. "Bionics # Biomimetics # Biomimicry", available online : https://biologytodesign.wordpress.com/2012/05/08/design-biology-linguistics/
[12] Elshapasy, R. "Biomimetic approaches to increase sustainability", Arab Academy for Science, Technology and Maritime TransportCollege of Engineering and TechnologyDepartment of Architectural Engineering and Environmental Design
[18] Zari, M.P. "Biomimetic approaches to architectural design for increased sustainability", School of Architecture, Victoria University,PO Box 600, Wellington, New Zealand.
[20] "Learning from Termites How to Create Sustainable Buildings", http://biomimicry.net/about/biomimicry/case-examples/architecture/