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BIOMIMICRY
A 21ST CENTURY DESIGN STRATEGY INTEGRATING WITH NATURE IN A SUSTAINABLE WAY

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Abstract:

Architects over the past half century have been trying to master nature with the aid of technology, machines and over rated energy consumption, thereby increasing the gap between nature and the built environment. With insulated glass, Air-conditions, central heating, we have been able to design cool spaces no matter how hot it was outside, hot spaces no matter how cold it was, we have converted the spaces we live in into an emulation of machines. Our buildings begin to look similar, regardless of culture or climate. This loss of regional difference began to undermine the uniqueness of place removing us from understanding what local culture and climate have to offer.

The research focuses on the emulation of nature rather than the desire to dominate it. Biomimicry", which is new way of viewing and valuing nature, contributes in making the built environment similar to living organisms in many ways hence sustaining it. Buildings now evolve in response to climate and topography, changing form and composition to fit function, while regulating temperature and humidity to the greatest extent possible, sustaining as well as generating its own energy ,tapering limits, curbing extension from within as well as self maintaining. We have come to realize that by adopting a different relationship with nature through the process of Biomimicry",we would be introducing an era based not on what we can extract from the natural world, but on what we can learn from it. That is achieved by studying the forms, shapes, structures, processes, strategies and mechanisms that nature has been using for billions of years, then emulate and use them in modern design.

he purpose of the research is to 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. Teaching students how to use Biomimicry as a tool for innovation will increase the integration of the built environment with nature in a sustainable way.

Conference Topic: future intermediate sustainable cities – a message to future generations
Keywords: Biomimicry, Sustainability, Teaching, Methodology, Nature.

Introduction:

"The best way to predict the future is to design it." (Buckminster Fuller) as seen in Leonardo Da Vinci designs for flying machines. Fig1. Analyzing this quotation we come to realize that academic members of different design fields are actually redefining the future. They have an obligation towards upcoming generations to paradigm shift their way of thinking in design

towards not only enhancing identity, functionality and aesthetic values, But towards the interpreting sustainable strategies and methodologies in integration with nature. Teaching students how to view nature as a model, measure and a mentor, will enhance the inspiration of new paths and the development of solutions for living synergistically in a balanced sustainable eco system on earth, and alter the evaluation criteria of the future built environment.
Today due to serious climatic changes, depletion of natural rescores, mal nutrient conditions, and different kinds of pollution which have direct impact on nature, the whole perspective of human need has diverted. Buildings now are functioning like living organisms, they are able to draw most of their requirements of energy and water from the surrounding sun, wind and rain, in an attempt to adapt to the environment that has the ability to stay put without consuming its ecological capital and holds the secrets of its creation implanted in it by God. This diversion in need is achieved by adopting a different relationship with nature. Biomimicry", which is considered a sustainable design tool is based on emulating forms, structures, processes and strategies used by living things and different species to perform functions that we want our technologies to perform, thereby introducing an era based not on what we can extract from the natural world, but on what we can learn from it, emulate and use in modern design.

Even though various forms of Biomimicry or bio-inspired design are discussed by researchers and professionals in the field of sustainable architecture (Berkebile,2007) the widespread of teaching Biomimicry as tool for sustainability in design curriculums remain largely unrealized.

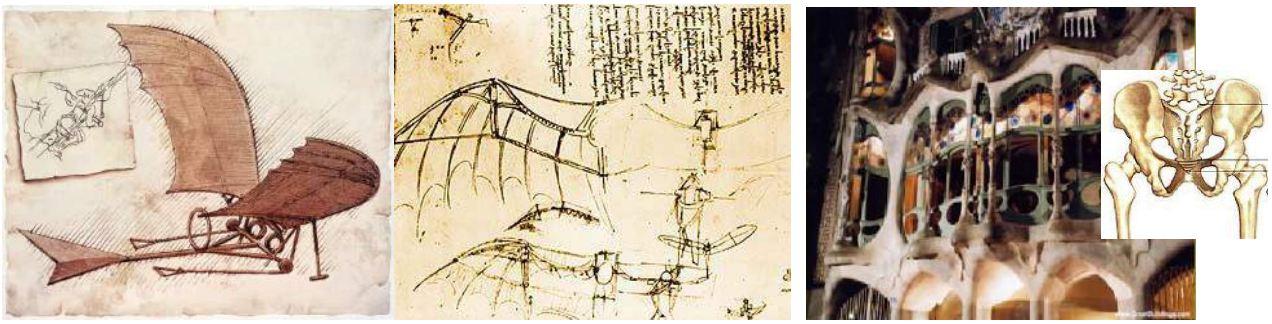

Fig. 1 . (left) Leonardo Da Vinci's drawings for the flying machine. One of earliest Biomimetic designs in the 13th century.
Fig 2 (right). Antonio Gaudi Casa Batllo- Barcelona- Spain

THE EVOLUTION OF MANKIND RELATIONSHIP WITH NATURE:

Fig 3 diagram showing the evolution of the relationship of mankind with nature

Human relationship with nature has evolved from the beginning of creation starting as early as Adam's sons, learning the burial rituals from imitating the raven (Quran surah Al Maedah 27-31) , emphasizing by this act the fact that we are all made from dust and to dust we shall return, closing the loop of the eco system of human life. From then on the relationship changed from fear to imitating nature, where Cavemen were able to learn many things from observing natures species and by they were able to compromise fear of the unknown and lack of knowledge.
Ancient Egyptian, Greeks, early inventors and engineers have also turned to nature for inspiration and ideas. Leonardo Da Vinci in the 13th century was a big proponent of learning from nature and used it as a source for inspiration. The Wright brothers and other flight pioneers commonly observed birds. Victor Horta's 17th century designs where inspired from

nature ,where as in the 18th century Antoni Gaudi's Casa Balto design was , inspired by human skeletons. Fig(2)

With the increase of technology the relationship with nature diverted from inspiration to "Domain over Nature" as sought by designers like Francis Bacon, when we began to put distance between the elements on the outside and activities held indoors, as to be warm no matter how cold it was outside and cool no matter how hot. With new design freedoms such as insulated glass, air conditioning and central heating systems, Architecture moved quickly away from considering nature as a model of inspiration, towards the domain over nature phase. It was the machines that made these changes possible, (Berkebile 2007) to the extent that le Corbusier went as far as saying "Houses are machines for living in". The relationship with nature was then altered to a more adaptive form through Organic Architecture in an attempt to integrate the spaces into a coherent whole, and the adaptation between the site and the built environment.

In modern Architecture Louis Sullivan's slogan "form follows function" was later altered by Franck Lloyd Wright to "Form and Function are one," using nature as the best example of this integration. Today due to the drastic effects of the domain over nature phase, the whole perspective of human need is being shifted towards a different slogan "Function Follows Need". The need to adapt our built environment to nature, learn from it instead of learning about it, in search of innovative methods to solve nutrition problems, adaptation to climatic changes, renewable energy recourses, in an attempt to improve the quality of life for upcoming generations and live sustainably on earth, hence moving mankind from the industrial age into the biological age.

That is why I believe it is time to paradigm shift our way of thinking about solving design problems towards fulfilling human need, diverting the slogan to "Function Follows Need" achieved identifying a strategy for teaching Biomimicry as tool for sustainability, along with a recommendation to include it in design curriculums. This paper focuses on the relevance of enhancing nature appreciation, followed by a shift in the way we think of nature from a source of extraction of materials to a model, a measure and a mentor, leading to a thorough understanding of nature's genius principals of design. It focuses on different approaches and applications of different levels of bio-mimicking, pointing out the necessary requirements needed to process the practice of Biomimicry as a tool for defining a whole new sustainable standard for our profession. It states a new methodology for innovation based upon life-sustaining principles and a sources of inspiration for aesthetic expression.

TEACHING BIOMIMICRY IN INTEGRATION WITH NATURE:

1. APRECIATION OF NATURE:

The first step in teaching Biomimicry is to nurture a caring, long-lasting, and meaningful relationship among people and nature. That is achieved through correlation of Ethics, morality and religion. On examining living beings we will witness the greatness of wisdom in their creation and see the indisputable evidences of God's creation without error, found anywhere from the wings of a bird to inside a bat's skull. Hence developing an increasing sense of gratitude to the soul creator, reaching an ardent desire to sustain and protect the genius that surrounds us. Without this relation any sustainable approach, including Biomimicry will merely replace conventional practices and prolong the increasing degradation of the natural and built environment.(Klein, Lance 2009). To achieve this goal, students should be motivated to look deeply into nature in search of insights, they must come to emulate and learn from its form, function, dynamic equilibrium and characteristics of ecosystem as far as possible, for

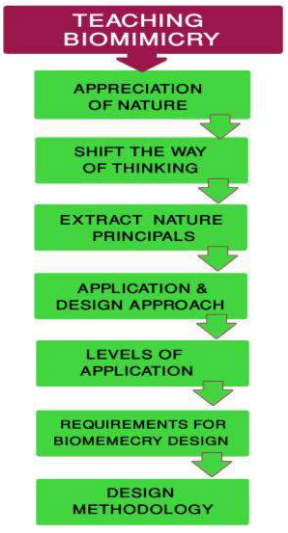

Fig. 4 Teaching Biomimicry Diagram in 7 stages

Learning from nature is learning from Allah's creations who designs all creatures at will, sustains the entire nature and holds absolute power and wisdom.

2. PARADIGM SHIFT THE WAY OF THINKING ABOUT NATURE:

God gave us the wisdom and will to learn, created nature to be our mentor for survival on earth, not merely a source of extracted goods. shifting our way of thinking, seeing nature as a model , a measure and a mentor will introduce an era based not on what we can extract from the natural world, but on what we can learn from it. (Benyus 1997)

2.1. NATURE AS MODEL – Biomimicry studies nature's perfect models takes inspiration from their designs and processes to solve human problems sustainably. We would manufacture the way animals and plants do, using sun and simple compounds to produce totally biodegradable materials used in interiors and architecture such as fibers, ceramics, plastics , solar cells emulating leaves, steely fibers woven spider-style, non pigmented colors from butterflies…..etc all perfect models for humanity to exploit.

2.2. NATURE AS MEASURE – Biomimicry uses an ecological standard to judge the 'rightness' of our innovations, according to natures life principals, not because nature has learned what works, what is appropriate and what lasts due to 3.8 billion years of evolution or because of error and trial as stated by (Benyus 1997),but due to the biological adaptation system implanted in it by its soul creator, to provide optimum functionality and of which is a prodigy of Gods existence and mercy to all who have wisdom and believes, as expressed in the Quran (Surah, Al-Hashr, 59:24).

2.3. 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. Biomimicry is a holistic way of viewing and valuing nature, the shift in thinking about nature will stimulate designers to look beyond the surface, see the unseen, play with the depth of field, leap with nature, and hence find new perceptions.(Biomimicry Guild, 2007).

3. INTRODUCING NATURES DESIGN PRINCIPALS:

Before formulating solutions that encompasses nature's principals. It is important to fully understand that nature's unique characteristics and principals that can be applied and help develop Architecture and Design is as follows:-

- Nature fits form to function, utilizes a variety of non orthogonal forms and design methods in its constructions to ensure maximization in terms of structural efficiency. It minimizes the required input of material. Curvilinear shapes are more efficient in terms of structural strength to weight ratio, stress and strain, integration with aerodynamics and multidirectional forces.(Panchuk 2006)
- Nature recycles everything, Uses waste as a resource, Creates structures using materials that are non-toxic and can be fully recycled at the end of their life.
- Nature uses an ordered hierarchy of structures.(*Zari 2009)*
- Nature banks on diversity, constantly mutating and adapting in a flexible and dynamic flow of change, increases its complexity, diversity and efficiency over time.
- Nature runs on sunlight,(Benyus1997). It responds actively to the sun to maximize energy absorption. It relies on energy from geothermal vents on the ocean floor.

- Nature uses only the energy it needs, Gathers and uses it efficiently.
- Nature cooperates to fully use the habitat materials in site , it utilizes local expertise, ,(Benyus1997) (ones waste is the food for the other)
- Nature does not use hard boundaries/edges.
- Nature Self assembles and generates structural organization on all scales, from molecules to galaxies. Panchuk 2006)
- Nature is Resilient to changes and self healing.
- Nature Senses and responds to a variety of environmental factors acting on it .
- Nature is Beautiful, a model and indisputable evidences of God's creation without error**.**
- Nature Remains in balance with the biosphere.
- Nature Optimizes rather than maximize, (Benyus1997) using the least materials for optimal structure and function. Material in the honey bee hexagonal colonies shape is allocated only to the places where it is most needed. (Vincent 2006).

4. APPROACHES TO BIOMIMICRY:

Approaching Biomimicry as a design process or trend typically falls into two categories:

4.1. DIRECT APPROACH:

Defining a human need or design problem and the context of its creation first, then trying to find solutions for this problem through looking to ways other organisms or ecosystems solve similar problems,(Panchuk 2006) through the observation of organisms and ecosystems or available access to previous biological research and information . Designers in this case will be able to reach potential Biomimetic solutions without an in depth scientific understanding or collaboration with a biologist or ecologist. However translation of biological knowledge to a design setting will remain at a shallow level with limited scientific understanding. It is easy to mimic forms and certain mechanical aspects of organisms but difficult to mimic chemical processes without scientific collaboration.

4.2. INDIRECT APPROACH:

Identifying particular characteristics or behaviors in an organism or ecosystem and then using them as guidelines for developing industrial or architectural designs, (*Zari*,2009). 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. An example is the scientific analysis of the lotus flower emerging clean from swampy waters, which led to many design innovations (*Zari*,2009), including *Lotusan* paint which enables buildings to be self cleaning Fig(5). This approach reflects 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,2005). In this case biological research must be conducted and then identified as relevant to a design context.

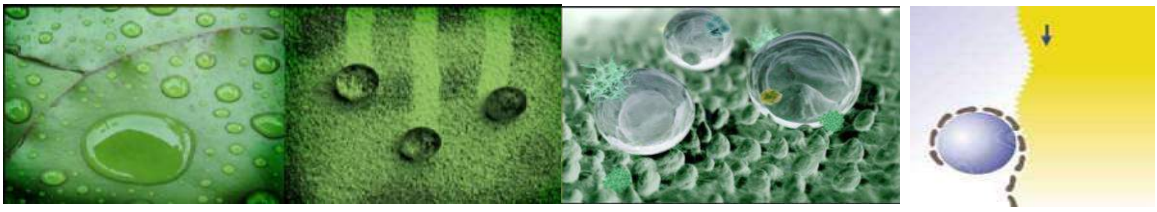

Fig: 5 The lotus effect – self cleaning method in nature. Mimicked into self cleaning paint.

5. LEVELS OF BIOMIMICRY APPLICATION :

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 (Biomimicry Guild, 2007). Within each of these levels, a further five possible mimic dimensions exist. The design may be Biomimetic in terms of what it looks like (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).

5.1 ORGANISM LEVEL:

The organism level refers to Biomimicing a specific organism like a plant or animal and may involve mimicking part of or the whole organism's form, material, function and process. The Minister of Municipal Affairs & Agriculture (MMAA) in Qatar Fig(6), is an Architectural Biomimicry example of the cactus non orthogonal aerodynamic plant shape, mimicking the function of the cacti in the way that they successfully survive in hot, dry environments, taking inspiration from the way these plants deal with the desert climate. The botanic dome at the base of the tower will provide sustainable food source irrigated from Grey and black water treatment, this Process is implemented with the use of sun shades that can open or close automatically according to the intensity of the sun during the day to keep out the heat when it is too much. This is similar to how a cactus chooses to perform transpiration at night rather then

Fig: 6 Architectural example demonstrating Biomimicry at the Organism Level
(Cactus Building, (MMAA) in Qatar)

In Interior Architectural field, Furniture design studio also contributes with Biomimic solutions in design mimicking spider webs and fish skeletons in shape strength and streamline.fig.(7,8) Design studio 7, KFU Environmental Science Research Center student design following the biomimicry strategy suggested, mimics a green leaf in form , function as well as its ability to run on sunlight, generate and gathers and uses energy efficiently, contains botanical planters, and the outside landscape is irrigated with treated gray water. Fig.(9).

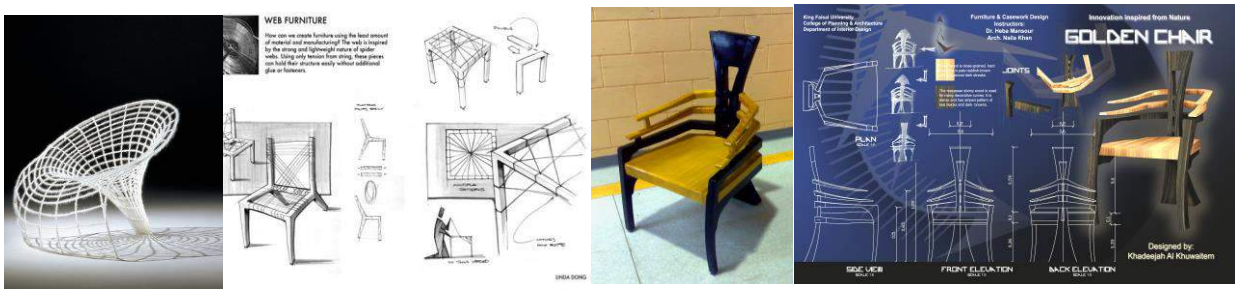

Fig.7 (left) Web furniture Chair design by biomimicry guild workshop mimicking the spider web which is proven to be 5 times stronger then steel, function : the woven idea of assembling.
Fig. 8 (right) Golden chair: KFU student design mimicking the fish exoskeleton in streamline , minimal material usage, in the organism level of biomimicry

Fig.9 Interior Architecture example demonstrating Biomimicry at the Organism Level, Environmental Science research center, student design based on the organism level of a green leaf in KSA

5.2 BEHAVIOR LEVEL:

The behavior level of Biomimicry is the mimicking of how an organism behaves, adepts, functions or relates to it larger context. Mimicking the process of the natural structure of the South American butterfly's wings produced a non pigmented sustainable paint and fabric called Morphotex, where different colored flakes catch light depending on the viewing angle and the incident angle at which light hits the painted surface, creating a dramatic color shift that is visible even in low light. This technique has the potential of creating sustainable colors without chemicals or the addition of heavy metals, (materia newsletter 2009). fig(10)

Fig.10 (left) Coloration by light using non pigment colors (mirasol effect).
Fig.11 (right) Passive Cooling -Eastgate center building in Zimbabwe

In the Architecture behavior level, Eastgate convention Centre tower-buildings in Zimbabwe was designed to mimic the heating and cooling systems termites use in their mounds. 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. The innovative building uses similar behavior in the design, and air circulation planning consuming less than 10% of the energy used in similar sized conventional buildings, hence moving towards a more sustainable building .fig(11)

5.3 ECOSYSTEM LEVEL:

The mimicking of ecosystems is an integral part of Biomimicry as described by Benyus (1997) and Vincent(2007). The term Ecomimicry has also been used to describe the mimicking of ecosystems in design (Lourenci , 2004, Russell, 2004), while (Marshall,2007) uses the term to

mean a sustainable form of Biomimicry where the objective is the wellbeing of ecosystems and people. It is based on the deconstructing of the design problem into performance characteristics, of functions, processes and past solutions, then mimicking the common principles of the genius of nature that are relevant to the design problem, allowing them to function in a successful sustainable way as a part of a complex system and utilizing the relationships between different processes in nature thereby reaching a total emulation of the whole ecosystem, (Reed,2006).Fig(12) The biomimetic design doesn't have to mimic a specific organisms form in that context. Earthships Fig(13-16) is an example of ecosystem level of Biomimicry , designed to integrate with nature based on six natural design principles:-

5.3.1. Constructed with recycled and local materials: Tiers, sand bags, adobe….etc.
5.3.2. Heating and Cooling: From the sun and the earth.
5.3.3. Water Harvesting: Caught on the roof from rain and dew mimicking the Namibian beetle bumpy body.
5.3.4. Renewable Electricity: Photovoltaic / wind power system. This energy is stored in batteries and supplied to electrical automated outlets, including grid-intertie.
5.3.5. 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.
5.3.6. Food production: Food is grown inside with botanical planters and outside in landscape irrigated with treated gray water.

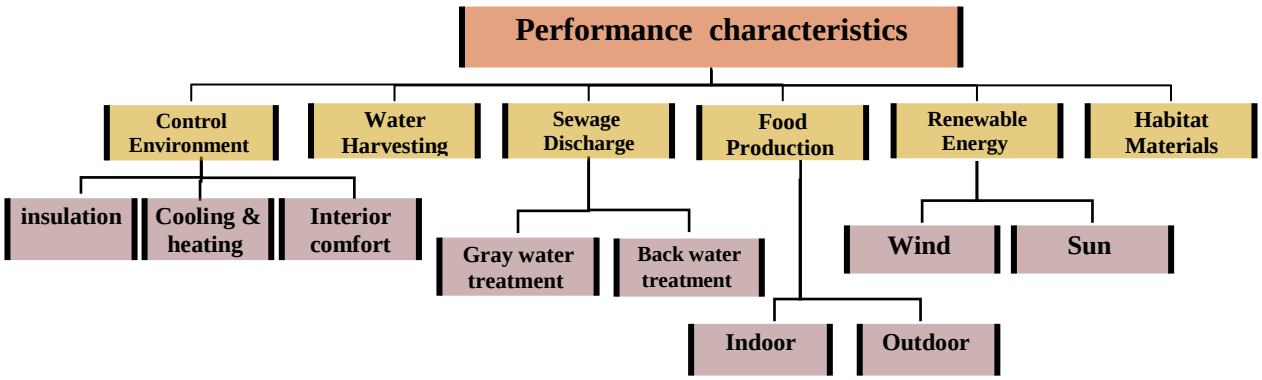

Fig. 12 performance characteristics diagram of the Earthship deconstructing the design needs, functions to translate them into biomimicry for deeper sustainable integrative solutions.

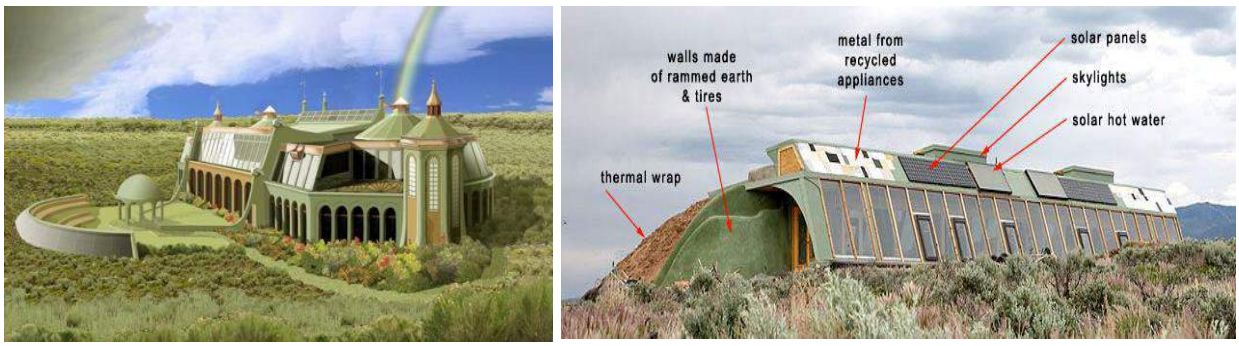

Fig. 13 Earthships are sustainable homes made of recycled materials, designed to integrate with nature as an example of biomimicry in the Ecosystem level


Fig. 14(left) interior botanical cell in Earthships.
Fig. 15 (right) photovoltaic solar cells for renewable energy.


Fig.16 Earthship interior bathroom design constructed with natural recyclable materials.

Another unconstructed Architectural example of Biomimicry in the Ecosystem level is the William McDonough's Treescraper Tower of Tomorrow is imitating a tree in distilling water, producing energy, changing with the seasons. The form of the building is aerodynamic, reducing the impact of the wind, reducing the amount of materials needed for construction, increasing structural stability and maximizing enclosed space. It contains a green roof and three-story atrium gardens. The wastewater from sinks and bathtubs would be recycled and used for irrigation of building gardens. The wastewater from gardens could further be reused in toilets using wetland system, using microorganisms and plants to purify water. The southern façade would be made of about 100,000 square feet of photovoltaic panels that convert sunlight into electricity. The robust system could provide up to 40 percent of the building's needs.
A combined heat-and-power plant would also be installed, to be fueled by natural gas, which could supply the power that the solar panels cannot. All products, from building materials to furnishings, could be recycled emulating natures' Ecosystem.

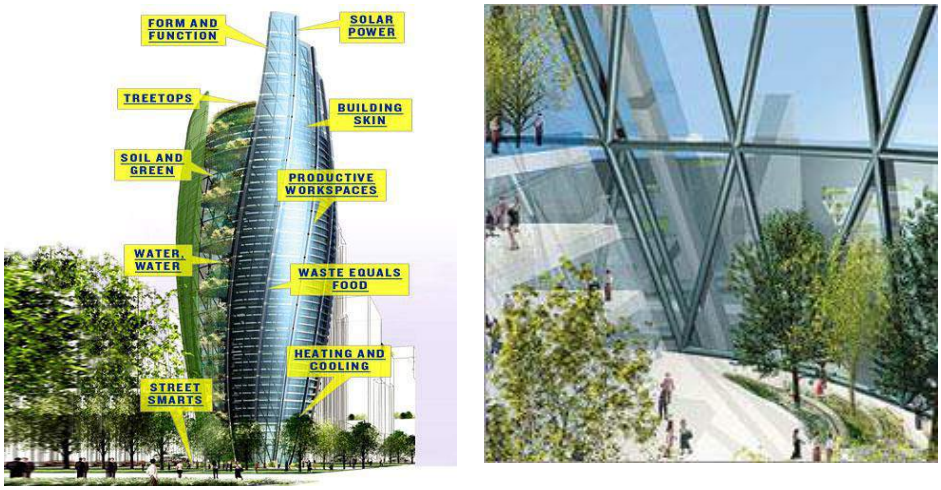

Fig.17 William McDonough's Treescraper Tower of Tomorrow

6. REQUIREMENTS FOR ARCHITECTURAL BIOMIMICRY DESIGN:

For teaching students to practice Biomimicry in design as a tool for sustainability there are some requirements needed to fulfill the educational system.

6.1. COLLABORATION OF PRACTICES:

Best way to teach biomimicry is through Interactive interdisciplinary settings, This means creating conditions for students to practice biomimicry with students from different disciplines, including electrical and chemical engineering, design, biology, and business.A Biomimatic sustainable design requires the thoughtful integration of a rapidly expanding palette of systems, structures and construction approaches. Current educational systems treat many practices, such as mechanical, electrical or architecture to name a few, as separate entities that are designed independent of one another and occupy their own partitioned space. While this approach may be useful in relatively uncomplicated spaces, its appropriateness begins to diminish when the complexity of building structure and layout begins to intensify. Therefore the collaboration between different practices is important to challenge conventional architectural design to be able to produce eco-designs based on the ecosystem level of Biomimicry. (Zari, 2009)

6.2. COMPLEX SURFACES 3 DIMENSIONAL MODELING:

The shift from sketch to CAD development is a hard-edged threshold in which abstracted and generalized spatial and geometric ideas and relationships become rigid. The study of updated Modeling Devise methods of generating 3 dimensional complex surfaces allow elements to be more easily designed and manufactured to decrease error, and reach innovation.

6.3. TECHNOLOGY AND SPECIALIZED INFO. FROM DIFFERENT PRACTICES:

The engineering library is growing in its fabrication, materials, techniques and abilities (Collyer, 2001; Dickinson, 1999). Technology is finally advanced enough enabling us to probe to the molecular and mechanistic levels of biology, with the aid of Nano technology access to critical information and the ability to develop and analyze is more efficient**.**
For architects to reach the deepest level of Biomimicing, sufficient biological, physiological, mechanical data about nature and its species should be available, otherwise designs will only reach partial mimicking , lacking the whole point of sustainability.

7. DESIGN METHODOLOGY

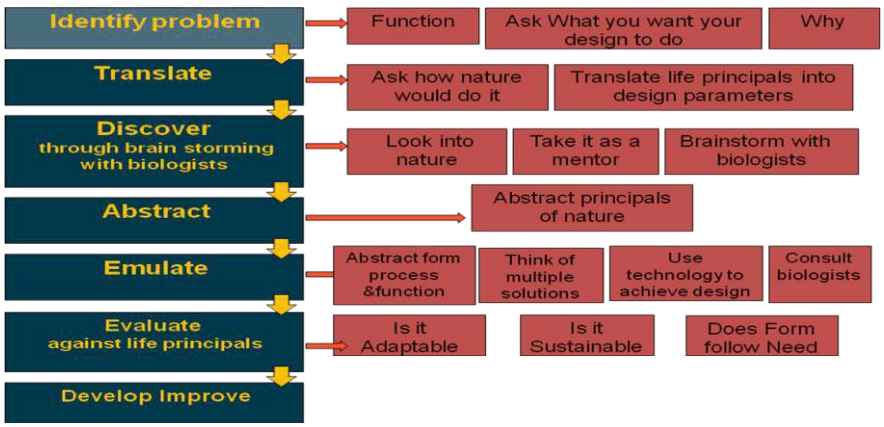

Fig.18 Design methodology diagram based on Benyus's Challenge to Biology Design Spiral.

7.1. IDENTIFY THE PROBLEM:

Identify the function you want your design to accomplish, what do you want your design to do? Not "what do you want to design. Think about the design challenges from a different perspective. Start by deconstructing the problem into functions, processes, past solutions and constraints, then by asking how nature might approach each individually; start to organize that decomposition into a whole visual framework, exploring the big concepts within your own situation as starting points. Define who is involved with the problem and who will be involved with the solution, where is the problem, where will the solution be applied.

7.2. TRANSLATE LIFE PRINCIPALS INTO DESIGN PARAMETERS

Making the design connection between the design problem and the natural world. Translate the design into functions carried out in nature. Ask How does Nature do this function think of sustainability solutions at the earliest stages of the design. Define the Habitat/Location , Climate conditions , Nutrient conditions , Social conditions , Temporal conditions.

7.3. LOOK INTO NATURE AND DISCOVER:

Find the best Natural Models to answer questions solving your problem. Brainstorm your challenge with different disciplines such as biologists , mechanical engineering for availability in your design.

7.4. ABSTRACT:

Find the repeating patterns and processes within nature that achieve success, Create taxonomy of natures design principals , Select the champions with the most relevant strategies to your particular design challenge and need, Abstract from this list the repeating successes and principles that achieve this success. study the relations between materials, environment and performance.

7.5. EMULATE :

7.5.1. For Organism Emulation, start by photo shooting of different forms of life with direct or indirect relevance to your design problem. Find out details of the morphology of the shape , Understand scale effects , Consider influencing factors on the effectiveness of the form for the organism,(2007-2010 The Biomimicry Institute) look at nature with your own perception, see the unseen. Trace, sketch the photos, use modeling tools to gradually alter the form to fit function. Simplify and abstract using non orthogonal lines to reduce material usage. Consider ways in which you might also mimic the ecosystem.

7.5.2. For behavior emulation, start functional decomposition which can be explained as a series of states and transitions. Each complex behavior can be further broken down into more detailed functions, find out details of the biological process , Understand scale effects , Consider influencing factors on the effectiveness of the process for the organism , Consider ways to deepen the process into mimicking the ecosystem, using the appropriate technology to achieve optimal function through consulting biologists, physics and mechanical engineers.

7.5.3. For ecosystem emulation, study closely the sustainability methods of design and evaluation, find out details of the biological process, Understand scale effects, Consider influencing factors on the effectiveness of the process for the organism.(2007-2010 The Biomimicry Institute).

7.6. EVALUATE :

- Evaluate the design against natures design principals stated in section 3
- Identify further ways to improve your design's complexity and diversity that adapts and evolves.
- Develop further ways to make waste streams valuable to someone else.
- Deviate the evaluation of the design, to measure the extent of functional fulfillment of our vital needs "function follows need."
- Evaluate the outcome of the design Using sustainability strategies and methods of evaluation at early stages in design .
- Evaluate systems including energy systems and waste treatment systems, known as the Life Cycle Assessment (LCA) of the design (the practice of quantifying a product design's ecological impact.
- Evaluation according to LEED certificate credit -based system. According to 5 environmental impact areas, dividing the 64 credit points among:-
  - Sustainable Sites (SS)
  - Water Efficiency (WE)
  - Energy and Atmosphere (EA)
  - Materials and Resources (MR)
  - Indoor Environmental Quality (IEQ Leeds certificate of sustainability)(Chris,2002)

CONCLUSION:

The built environment is increasingly held accountable for global environmental and social problems with vast proportions of waste, material and energy consumptions' impact on nature. 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. By using the framework and strategy of teaching Biomimicry and including it in initial design parameters as suggested in this paper, it is possible to shift the future of designs into mimicking nature's design principals and developing it into a built environment, that is able to gather and use natural resources efficiently, diversify and cooperate to fully use the habitat, and is capable of functioning in a sustainable and regenerative way.

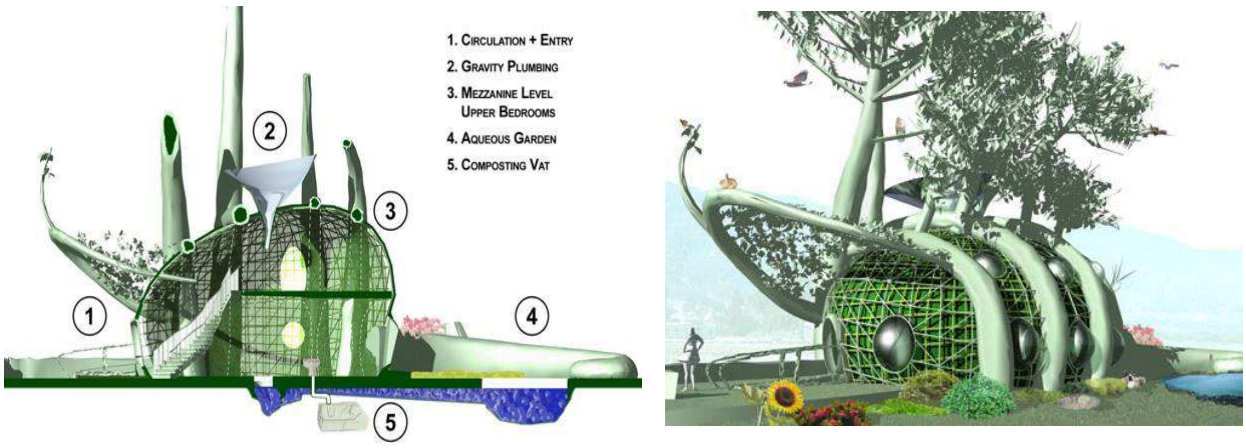

Fig. 19 Terreform 'FabTree Hab Treehouse' designed by Mitchell Joachim and Javier Arbona

It is also interesting to think what would happen if we were able to engage all of the principles of Biomimicry in architecture, such as running on sunlight or self-assembly. Perhaps one day

we will merely plant a seed, and from it will grow a house, built from the unique nutrients of the soil and driven on photosynthesis, interacting with and becoming a part of the local ecosystem. Already two architects spearheading the 'Fab Tree Hab Treehouse', Mitchell Joachim and Javier Arbona of the Smart Cities group of the MIT Media Lab, are working with Lara Gredem, an environmental engineer from MIT, to develop a house that grows itself. !!!

GENERAL FINDINGS:

- Explore the science of Biomimicry and tie it to current design education methodology curriculum, as an integrating concept promising new teaching paradigm for two main reasons. First, there is a need for the transference of optimism and hope in the dialog of environmental as well as innovative design issues. Second, it is one way to address the critical importance of education for a sustainable future.
- The clarification that Biomimicry will not only help us significantly reduce the environmental impact of our projects, but that it also has the potential to help define a whole new sustainable standard for our profession.
- Maintain A framework for understanding the various forms and levels of Biomimicry, used to discuss the distinct advantages and disadvantages inherent in each as a design methodology, which may lead to different outcomes in terms of overall sustainability or regenerative potential.
- Teach students how to develop their designs serving societal, environmental and economical needs , thus insuring a well sustainable approach in design.
- Teaching Biomimicry, as design philosophy learning from the genius creations in nature, will develop an increasing sense of gratitude, to the soul creator god and an ardent desire to sustain and protect the genius that surrounds us.

RESULTS AND RECOMMENDATIONS:

- Facilitate the integration of Biomimicry in academic curriculums of engineering and design as a futuristic method of reducing the impact on the environment , and maintaining sustainability, since Biomimicry is suggested to be the guiding principal for what I consider to be a paradigm shift to creative and problem-based learning necessary for education toward sustainability.
- It is recommended to teach Biomimicry through Interactive interdisciplinary settings, This means creating conditions for students to practice Biomimicry with students from different disciplines, including engineering, design, biology, and business.
- There should be a collaboration between different disciplines of Engineering and Applied Science and Biology to help designers reach the deepest form of sustainability in Biomimicry on the ecosystem level, aiming for a different outcome graduate student that is not an architect , nor a biologist or an urban planner but a biomimicature.
- 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 as described by the Biomimicry Guild(2007).

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