Using Biomimicry as an Educational Tool in Interior Architecture Design Studio

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ABSTRACT

Nature has always been a source of inspiration for human beings to solve their life problems. Since a few decades ago, methods based on inspiration from nature have entered to the world of design with various names too. Most of these methods emphasize on sustainable character of natural solutions and use of them is inevitable in current situation that world is facing with caused by unconscious use of natural resources. Biomimicry is one of these methods, which aims to use strategies developed in nature to create sustainable designs. Emphasis on education by pioneer organizations working on this field has led to spreading biomimicry approach among the research centers, universities and institutes. The interior architecture as a new design discipline has gradually been influenced by the sustainability movement too. Nevertheless still not many examples of biomimicry in interior architecture can be found around the world. This study relied on implemented examples, and the growing interest in biomimicry in education, and investigated the possibility of using biomimicry in interior architecture education, especially in design studio. To achieve this, the views and attitudes of the interior architecture instructors in Eastern Mediterranean University (EMU) who attend in studios about the topic are collected. In addition, to improve the study, about the possibility of collaboration with biologists in the design studios, the opinions of the instructors in the Department of Biological sciences in EMU were also collected.

This survey showed that despite of the interest of the instructors in both of the departments, lack of educational systematic methods and interdisciplinary collaboration tradition are the barriers in using biomimicry as a sustainable problem

solving method in the design studios. This research attempts to be a step toward closing this gap and a guide for instructors and researchers, who wish to use biomimicry in design education, particularly in interior architecture studio.

Keywords: Biomimicry, interior architecture, design education, teaching in studio, educational method, interdisciplinary design education

ÖZ

Doğa her zaman insanların yaşam problemlerini çözmekte bir esin kaynağı olmuştur. Bir kaç yıldan beri doğadan esinlenen yöntemler farklı adlarla tasarım dünyasına da girmiştir. Bu yöntemlerin çoğu doğal çözümlerin sürdürebilirlik doğasını vurguladığı için, doğal kaynakların hızla tükendiği günümüzde kullanımları kaçınılmazdır. Biyomimikri doğada bulunan stratejileri kullanarak sürdürebilir tasarımlar geliştirmeyi amaçlayan bu yöntemlerden biridir. Bu konuda çalışan öncü organizasyonların eğitime vurgu yapmaları biyomimikri yaklaşımının araştırma merkezleri, üniversiteler ve enstitüler arasında yayılmasına neden olmuştur. İç Mimarlık da yeni sayılan bir tasarım alanı olarak sürdürebilirlik kavramından etkilenmeye başlamıştır. Yalnız henüz bu alanda dünyada biyomimikri yaklaşımı ile tasarlanmış çok örneğe rastlanmak mümkün değildir. Bu çalışma, yapılmış örneklere ve eğitimde biyomimikri yaklaşım konusunda gelişen ilgiye dayanarak, İç Mimarlık eğitiminde ve özellikle tasarım stüdyosunda biyomimikri yaklaşımın kullanım olanaklarını araştırır. Bu amaçla Doğu Akdeniz Üniversitesi, İç Mimarlık Bölümü'nde tasarım stüdyosunda eğitim veren öğretim kadrosunun konu ile ilgili görüşleri toplanmıştır. Bununla beraber, çalışmaya katkı koyması açısından ve biyologlar ile tasarım stüdyosunda işbirliği olanaklarını irdelemek için biyoloji bölümündeki öğretim üyelerinin konu ile ilgili görüşleri de alınmıştır.

Bu çalışma, her iki bölümdeki öğretim kadrosunun ilgisine rağmen, eğitimde sistematik yöntemlerin ve disiplinler arası çalışma geleneğinin olmamasının (olmayışının), tasarım stüdyosunda sürdürebilir bir problem çözme yöntemi olarak biyomimikrinin kullanılmasına engel olan en önemli nedenler olduğunu gösterir. Bu

araştırma bu boşluğu doldurmak için bir adım atmaya ve biyomimikriyi tasarım eğitiminde, özellikle de tasarım stüdyosunda kullanmak isteyen hocalar ve araştırmacılar için bir rehber olmayı amaçlanır.

Anahtar kelimeler: Biomimikri, iç mimarlık, tasarım eğitimi, stüdyo eğitimi, eğitim yöntemleri, interdisipliner tasarım eğitimi.

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INTRODUCTION

Today's world is facing with serious problems such as the energy crisis, shortage in natural resources, climate change, environmental pollution, population etc. Most of these problems are caused by manmade environment and consequently the designed environment by man. That is why designers have a great role in producing these problems, and now it is time to face these facts and look for alternatives in design that prevent giving harm to our nature. Design is the phenomena that occur when a problem needs to be solved. With the conventional approaches, we can solve a problem but generally, we produce other problems for the world. Montana (2010) belives, design should be a conscious act that can be helpful to fulfill "mankind necessities" such as energy, water, shelter, comfort, and other concerns (Montana, 2010). Therefore, designers should look for other alternative approaches to design, that do not destruct the environment. This is why a lot of researchers and designers have begun to see the natural strategies to create better systems, objects and spaces to solve these kinds of problems and necessities.

For many years, nature was the biggest source of inspiration for human. Evolved and adapted strategies in nature through 4.5 billion years of trial and error are a countless source of ideas to solve human problems from micro to macro scales. Today, these ideas can be seen in many fields of design such as architecture, engineering, industrial design, business, medicine, etc. (URL 9).

Learning the techniques of nature for solving problems has helped humanity at the most stages of life (Vahedi, 2009). This relationship began, when human beings started to shelter themselves by imitation of animals' nests and using available natural materials such as foliage, wood, bones and stone (Figure 1). Thus, it was the first try to make a structure for living in the history of architecture (Mansour, 2010).

Figure 1. The premier shelters illustrated by Giovanni Caselli (URL 43)

Since then, many of primer ideas in architecture had direct relationship with nature. For instance, using the sun to make baked clay as a material of the structure to construct straight wall and embedded window (Vahedi, 2009), or finding and using more durable and local building materials such as stone, wooden timber, reed bundles and trunks of palm trees (Gruber, 2011).

On the other hand, nature played aesthetically significant role in most of architectural periods. For instance using organic shapes and plant-forms to make symbolical elements in buidings are observable on stone columns in Egyptian temples and Greek columns'capitals (Gruber, 2011), or use of natural patterns in decorative elements,

wallpaper, lighting and furniture design in the aesthetic movements at the beginning of the 20th (Grigorian, 2014; Stankiewicz, 2010).

This inspirational relationship between human and nature was not only in architecture. Many of inventions in life have been imitating nature since the beginning of time. For instance, according to recorded history of the Persian Empire, by mimicking natural water tunnels, they invented a subterranean waterway system (Ghanat) to bring water in their living place in 3100 years ago (Grigorian, 2014).

Nature inspiration also could be seen in many of Leonardo Da Vinci's inventions such as “Flying Machine” that was inspired by bat wings to simulate flight. He sketched many observations regarding flying. Although Da Vinci’s efforts were not successful, but his idea became an important source in inventing the premier airplane in 1903 (Versos & Coelho, 2011).

One of the notable examples of nature inspiration after industrial movement was Cristal palace in London designed by Joseph Paxton in 1851. The design of the roof of the this building was inspired by the certain species of Amazonian Lily and was structured by using glass, iron and wood materials (Figure 2). Crystal Palace was based on a design that allowed more sunlight into the space (Vincent, 2014). Although this building was destroyed after a big fire in 1936, but it can still be counted as a great example of applying natural forms in architectural structure (Nature Labs, 2014).

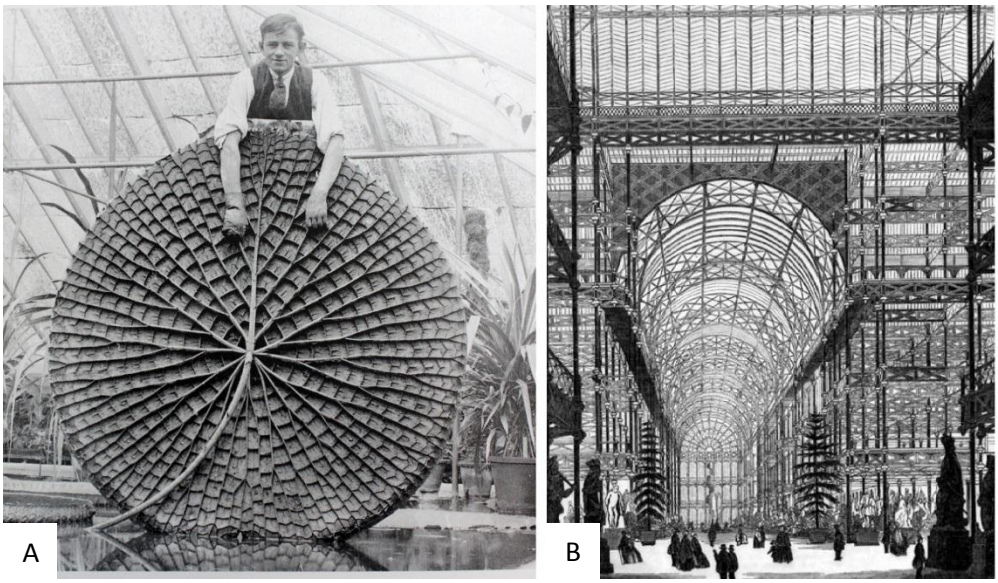


Figure 2. A. Amazon Lily (URL 31)
B. Structure of Cristal Palace in London (URL 26)

With the rise of industrialization, and development of technology, human beings began to use natural resources and unconscious manner. Humankind damaged environment by many of these inventions, which caused as excessive use of fossil fuel and mines, loss of forest areas, damage to animals' community, air and water pollution (Sproule, 2010).

Therefore, need to solve human problems without destroying nature becomes a concern in design. To increase the environmental quality and productivity, natural inspiration methods have gradually been appeared in the last fifty years. Bio inspiration design (BID) is known by different terms such as Bionics (1958), Biomimetics (1969), Design with Nature (1969), Ecological Design (1970s), Biomimicry (1997), Ecomimicry (2007), Nature-Inspired Design Strategies (2010) (Mead, 2014). All of these approaches have similarities in using natural inspiration for design and most of them "move towards the goal of a sustainable development in the last 30 years" (Mead, 2014, p. 217). For example, Ecological Design emphasizes

respect to the environment and reduces energy consumption through carefully considering of structure, to improve quality of life. Alternatively, the practice of “Ecomimicry” is based on mimicking the natural world with using technological inventions.

Biomimicry as a well-known approach in natural inspiration is highly improved in recent years and many biologists, engineers and designers actively attempt to utilize and integrate biomimicry in many design projects (Gardner, 2012). Benyus (1997) defines biomimicry as “a new science that studies nature's models and then imitates or takes inspiration from these designs and processes to solve human problems" (Benyus quoted in Todd, 2012, p.168).

Although, this inspirational approach was appeared at 1997, but its theory has been practiced many years before. An American inventor and engineer, Otto Schmitt developed the idea in 1951. He worked on this subject during his doctoral research and named his idea as Biomimetic, which is the combination of two words, bio, and mimic. “Bio” came from bios means life and “mimic” means imitating (Flint, 2015; Vincent et al., 2006).

Janine M. Benyus developed this study by publishing a book called, “Biomimicry: Innovation Inspired by Nature” in 1997. This book popularized Biomimicry and made it well known for the first time (URL 15). It soon became obvious that the interest in biomimicry was formed and the existence of an institute became necessary. Therefore, Benyus and colleagues founded the Biomimicry Institute in 2005, “as the primary sources for ideas about what is biomimicry as a concept and as an approach to design, development, science and research” (McGregor, 2013, p. 58).

Biomimicry movement opened a new dimension of natural inspiration in the design and achieved promising efflorescence through numerous activities around the world. The global spread of this phenomenon has influenced scientific and research centers around the world. Many professors and researchers from dozen universities in the world embed biomimicry in their design projects. The map below determines global expansion of biomimicry and showing biomimicry institutes and research centers around the world (URL 42).

Figure 3. Global expansion of biomimicry (URL 42)

Lynn Reaser, the pioneer financial analyst in biomimicry asserts, "Scholars published 2,560 research papers on biomimicry in 2013" (Reaser, 2014). In addition, the following pie chart is a global analysis from the number of publication of scientific papers in this area, which indicates biomimicry progress in each continent of the world at the first six months of 2015 (URL 40).

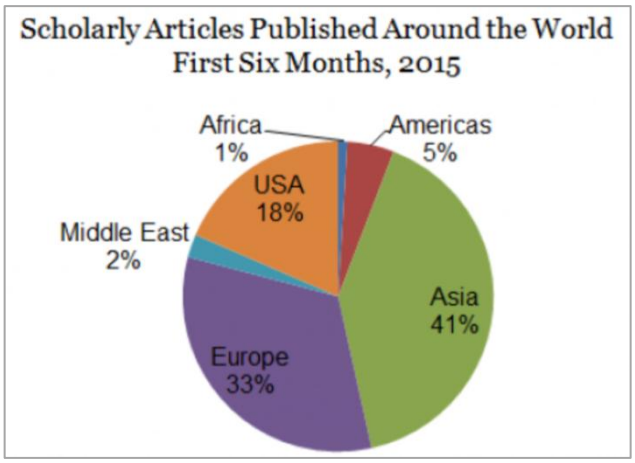


Figure 4. Percentage of biomimicry articles around the world (URL 40)

1.1 Problem Statement

This study believes that, it is time to focus on solving major problems through sustainable processes such as biomimicry. This green strategy should divert on design education and "can engage students in problem solving, creative thinking and collaboration, and introduce them to some of the innovative technologies that will provide the jobs of tomorrow" (Schroeter, 2010, p. 13). Given the many educational studies on biomimicry in recent years, and the popularity of using biomimicry in educational centers around the world, this study focuses on using biomimicry in interior architecture education. Despite the increasing number of activities in biomimicry such as events, workshops, education programs, summits, projects and sources, this method have not been much included as an educational approach in interior architecture programs particularly in studio education. On the other hand, it is hard to find documents about experiments on ways of teaching, instructions or pedagogical approaches when using this method in the design studio.

1.2 Aim and Objectives

According to these problems, the main aim of this study is to explore the possibility of using biomimicry as an educational tool in interior architecture design studio. In addition, the objectives of the study include:

- To explore the implementation of biomimicry and its examples in interior architecture.
- To find the reasons why biomimicry is not used widely in interior architecture.
- To investigate methods used in this approach and reveal the reluctance of its usage in interior architecture education.
- To explore the experiments that can be used as an educational approach in interior architecture studios.

1.3 Methodology of Study

This study is a qualitative and quantitative research, which is based on the literature survey on two concepts of biomimicry; and its relation to design education. To explore the definitions of biomimicry, many related sources, books and articles have been studied as the primary source of this survey such as “Biomimicry: Innovation Inspired by Nature, written by Benyus (1997)”. Moreover, the important digital sources and websites, such as “Biomimicry Institute” and “Biomimicry 3.8” were investigated to get a full understanding of what sources are available about the topic. In the first part of literature survey, the concept of biomimicry and several ways to apply biomimicry have been studied. Then, the examples of biomimicry’s application in architectural design and other disciplines have been collected. Afterwards, the educational topics and resources about biomimicry in education have been studied to figure out the appropriate instructions and methods in interior

architecture education. Consequently, three exemplary studio experiments in design studios related to interior architecture are described in detail in this part.

The case study of this research is composed of two parts. The first part is done in the Department of Interior Architecture in Eastern Mediterranean University and the second part is done in the Department of Biological Sciences. The first part of this study aims to evaluate the level of awareness about biomimicry in instructors in the Department of Interior Architecture. Besides, what is the relation between the level of awareness and level of application of biomimicry in studios? Since, biomimicry method is not using widely in the studios of this department, what are the reasons behind this fact? To find the answers for these questions, all of the 14 instructors in this department who attend in design studios were selected as sample for the study. Interview with open-ended questions was used as a method of data collection. The instructors could choose to fill the questionnaire and send it back to the author too.

Literature on Biomimicry, discuss about collaboration with biologists as a contributory way to facilitate the biomimicry method in design studio. EMU as a campus university has a great potential for creating a platform for this collaboration. Thus, the second part of this study was conducted as interviews with 3 full time instructors in the Department of Biological Sciences. At first, this part aims to investigate the possibility of interdisciplinary collaboration between two Departments of Interior Architecture and Biological Sciences. Second, this part of study aims to figure out the abilities of instructors to provide necessary information related to biology or attend the studios. The third aim of this part is to find the problems that exist in the way of interdisciplinary collaboration between the two departments.

Chapter2

BIOMIMICRY

2.1 Definition of Biomimicry

Various species of animals, plants or even human beings have been facing with the harshest conditions on the earth, such as drought, glacial or other environmental changes. Thus, they have been forced to adapt themselves to the environment and have gone forward to find a solution. In this regard, all creatures in the world can be useful sources of inspiration to find proper solutions for design if we can explore and investigate them carefully. Now Biomimicry as a sensible mimicking approach can catch pre-solved solutions from this endless source of information to utilize in design for human being.

Benyus (1997) believes that nature is similar to a library with a billion years of information and full source of inspiration that is waiting to be studied and used (Benyus cited in Bakırlıoğlu, 2012). Biomimicry will take us into this library, where humans have always been looking for solutions to their problems, for instance, when they modeled animal claws to make sharp tools or when they learned how leaves could store water to create a simple bowl (Mansour, 2010).

Today with further study and investigation in nature, we are aware of creatures as consummate engineers in the world (URL 7). They have “great potential to change the way we grow food, make materials, harness energy, heal ourselves, store

information, and conduct business" (Friend, 2009, p. 102). Benyus believes that solutions to design problems can be achieved through looking to nature as model, as measure and as mentor. Benyus (1997) explains these three viewpoints as:

- "Nature as model, studying nature and inspiring from its designs and processes to solve human problems.
- Nature as measure, an ecological standard to judge the 'rightness' of our innovations.
- Nature as mentor, a new way of viewing and valuing nature, not what we can extract from but what we can learn from" (URL 28).

An example is when Kingfisher was "modeled" to redesign one of the noisiest trains in the world (Figure 5). As Benyus explained in TED conference: "Beak of kingfishers and diving ability into water with little splashing, was modeled to redesign a quieter and faster train with using 15% less electricity" (Benyus, 2009).

Figure 5. The Japanese bullet train modeled from kingfisher, which can dive into water for fishing without much of a splash (URL 24)

Consequently, when we are looking to find efficient solutions to design problems, the only real model is nature that has worked for long periods and is truly sustainable. Biomimicry is the science and art of emulating these sustainable ideas in

human design (URL 16). Therefore, sustainability is one of the important aspects related to biomimicry approach and the next section will continue to discuss about this crucial aspect.

2.1.1 Biomimicry and Sustainable Design

With the expanding population on the earth and humankind insisting on the destructive and unsustainable habits, thinking about sustainable design becomes more critical as days pass. In the light of these global concerns, there is a great need to think about living spaces with more efficiency, and products and processes that have less environmental impacts.

Michael Pawlyn, the author of 'Biomimicry in Architecture' believes that three changes should be considered in all disciplines for the environmental challenges; we need to face in the years ahead. First, achieving radical increases in resource efficiency, second, transition from fossil fuels to solar systems, third, change the wasteful and polluting ways of using resources to clean approaches (Pawlyn, 2011). These three key goals will not be easy to apply, but are inevitable in the coming years, thus, if we insist on making it possible, biomimicry will be ready to help us. This section is an attempt to show how biomimicry can help us in this regard.

Many authors (Benyus, 1997, Pedersen Zari 2007, Bakırlıoğlu, 2012, Drake 2011, Chambers 2011, El Zeiny, 2012, Pawlyn, 2011, Anous, 2015, Gamage, 2012) believe that sustainability is one of the most striking features of biomimicry. As described by Biomimicry Institute in 2015, "Biomimicry is an approach to innovation that seeks sustainable solutions to human challenges by emulating nature’s time-tested patterns and strategies" (URL 16). Research by Chambers (2011) argues why nature is able to provide the sustainable ideas:

Natural organisms and processes rely only on biological practices, which generally happen in an appropriate, life-friendly range of conditions and are mainly composed of a limited range of multifunctional components. Hence, copying these components and processes, can lead to decreased environmental impacts; consist of reduced resource and energy usage (Chambers, 2011).

Therefore, by mimicking biological evolution, we could design with high-level of sustainability for this era and the future. Shortly before his death in 2011, Steve Jobs said, "I think the biggest innovations of the 21st century will be at the intersection of biology and technology. A new era is beginning" (Jobs quoted in Yoneda, 2012). Yoneda (2012) believes that, the crossroads that Jobs spoke is biomimicry, and Mother Nature is one of the universe's most incredible designers (Yoneda, 2012). To prove this claim, 'inhabitat.com' that is a weblog devoted to the future of sustainable design and clean technology, catalogues the great ideas in nature inspiration. Some of these examples are introduced in this part.

Scientists at the University of Exeter invent a new generation of solar panels by nearly 50 percent increasing output that is inspired by the V-shape wings' posture of White Butterfly to absorb maximum energy to move muscles for flying in both sunny and cloudy days (Lofgren, 2015). Figure 6, shows increasing temperature of the butterfly body in 10 seconds due to its posture, which can be used to design photovoltaic concentrators in solar panels (Shanks et al., 2015).

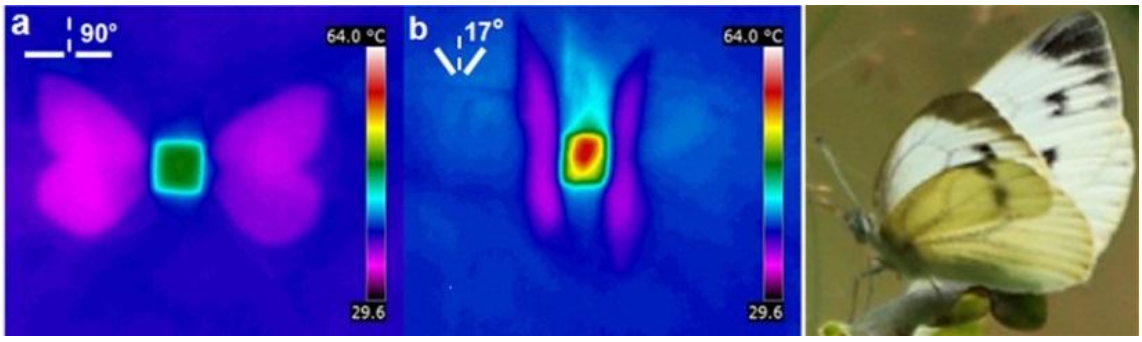


Figure 6. Thermal analysis of butterfly in 10 seconds when the wings are open (90°) or in a V-shape (17°) (Shanks et al., 2015)

Through the development of bio batteries, Researchers at the University of Utah have created a battery based on the process of metabolism (Figure 7). As the lead developer Shelley Minteer explains, in the same way that a child converts sugar to energy, using sugar as fuel, we catalyzed it with the natural energy conversion properties of enzymes pathways to apply to the battery (Minteer cited in Monks, 2014). In comparison to traditional batteries, the bio battery can function in extremely low temperatures due to its versatility and can already be used in devices such as smartphones and tablets (Monks, 2014).

Figure 7. Using sugar as a fuel to develop Bio-battery (Monks, 2014)

Another example that can be discussed about the relation of biomimicry and sustainable design is sticky tape inspired from Geckos. This reptile has the ability to

scale smooth walls and scamper upside-down across ceilings. The source of their grip is millions of microscopic hairs on the bottom of their toes (Figure 8). Scientists estimate that the setae from the tiny toes of a single gecko could theoretically carry 250 pounds and interestingly, by changing the direction of the setae, the grip is instantly broken and there will be no sticky residues. A team in University of Massachusetts, Amherst, researchers has developed Geckskin, an adhesive so strong, inspired by geckos that can hold up to 700 pounds. A form of gecko tape could replace sutures and staples in the hospitals. The ability to make gecko-tape gloves and climb the walls like Spiderman may not be far off (URL 45 & Mangels, 2012).

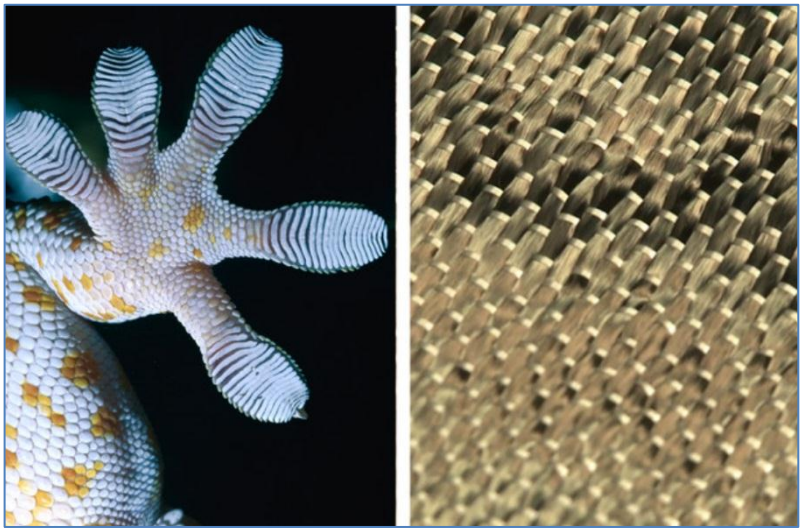


Figure 8. The adhesion property of geckos has inspired creation of a strong sticky tape (URL 45)

Therefore, biomimicry encourages designers to create sustainable designs through copying of life's principles. These principles as crucial criteria in sustainable inventions, at first were identified in the book "Biomimicry: Innovation Inspired by Nature" (1997):

- "Nature runs on sunlight.
- Nature uses only the energy it needs.

- Nature fits form to function.
- Nature recycles everything.
- Nature rewards cooperation.
- Nature banks on diversity.
- Nature demands local expertise.
- Nature curbs excesses from within.
- Nature taps the power of limits”

(Benyus quoted in Lynch Caris et al., 2012, p. 4)

Few years later, these principles were developed and presented as a tool in multiple scales by “Biomimicry 3.8” organization. It is the most crucial and influential component of biomimicry, and the most comprehensive tool for designing anything that is named “Life’s Principle” (URL 12).

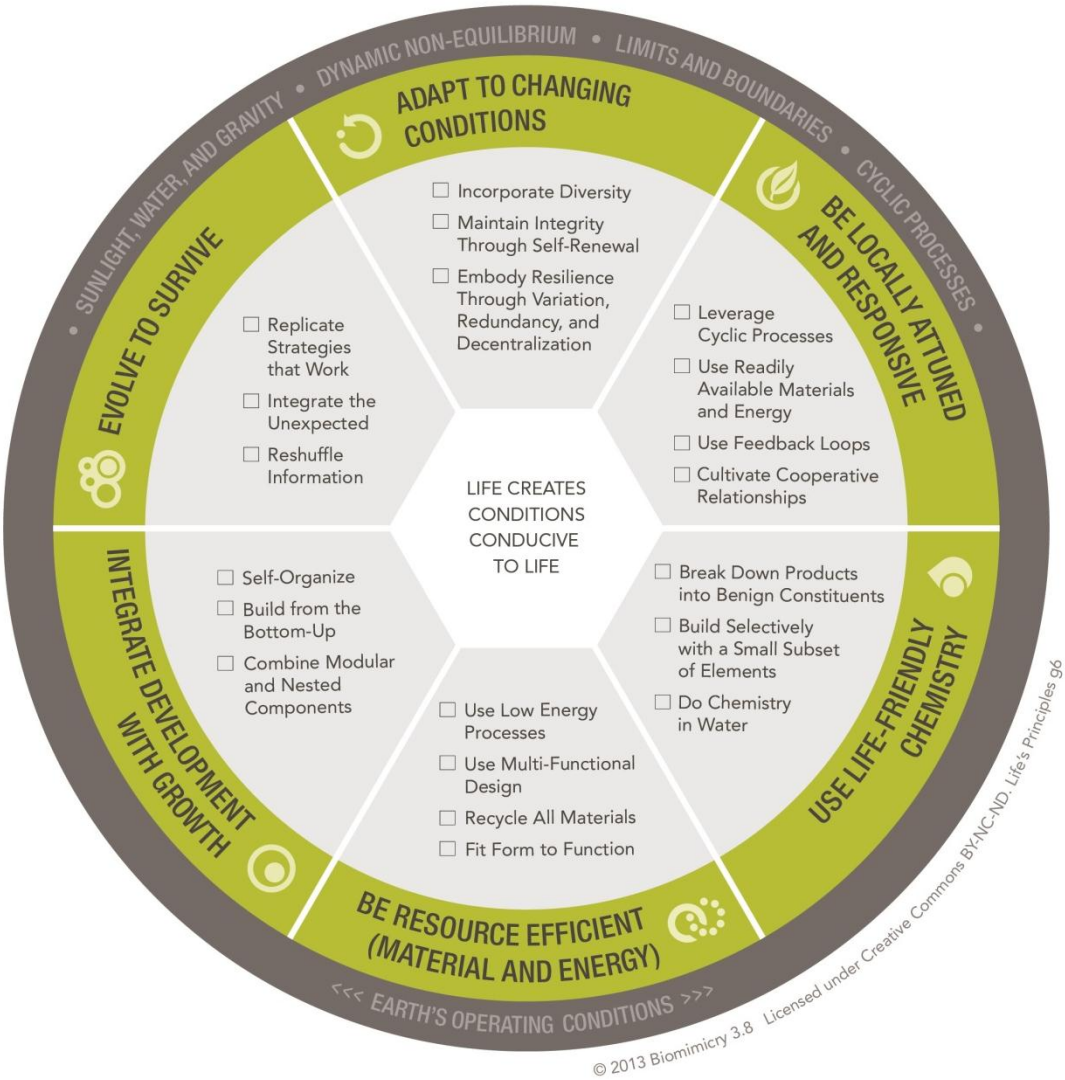


Figure 9. Nature principles diagram by Biomimicry 3.8 in 2013 that includes 6 sustainable benchmarks to modeling innovative strategies of nature (URL 12)

These components represent the patterns that are used by species to survive on Earth. Bouncing Ideas' Weblog states that, they are the deep criteria for flourishing and surviving on earth and by establishing these conditions and applying these principles, designers can prevent superficial biomimicry. Because, each principle challenges humans to think systemically within an expanded context rather than a single organism (URL 19).

Therefore, biomimicry can be a development process, especially for designers in architecture and interior architecture who are ready to take advantage from the merging process of biomimicry in their design. Next section will discuss how biomimicry can be used in the design process as a useful approach.

2.2 Biomimicry Process

Many writers (Benyus, 1997; Pedersen Zari, 2007; Mansour, 210; El Zeiny, 2012; El Ahmar, 2011) have pointed out to the particular importance of biomimicry process as a hopeful approach in design. As it is mentioned in the previous section, biomimicry follows the natural principles by emulating the possible and sustainable solutions and it is the specific purpose of biomimicry in design process. Rossin (2010) believes, that "the application of biomimicry principles during the design process will move the designer into a new era of sustainable applications, technologies and approaches" (Rossin, 2010, p. 569).

The process of biomimicry will be beneficial when the biological information is considered deeply, and prevents a superficial mimicking in the process (Benyus, 1997; Pedersen Zari, 2007; El Zeiny, 2012). But the question is, how the process of biomimicry can be done, according to these principles; and what tools are needed to do this? This section is going to answer this question by bringing together the main findings on biomimicry process, introducing the main methodologies used, and the essential tools aided in biomimicry.

2.2.1 Biomimicry Methodologies

Biomimicry as a design approach typically falls into two main methodologies:

- Challenge to Biology Approach
- Biology to Design Approach

These methods can be seen in different references with different names. For example, Challenge to Biology can be recognized as ‘Design Looking Biology’, ‘Direct Approach’, ‘Problem-Driven’, ‘Design Investigating Biology’, ‘Problem-Based Approach’ and ‘Bridging Design to Biology’; all of them are mutual versions of “Challenge to Biology” methodology. The other one, “Biology to Design” also have various name such as ‘Biology Looking Design’, ‘Indirect Approach’, ‘Solution-Driven’, ‘Biology Investigating Design’, ‘Solution Based Approach’, and ‘Bridging Biology to Design’. This variety of names can lead the readers to confusion, thus this thesis uses only the Biomimicry Institute’s term to explain these two methodologies in this chapter.

2.2.1.1 Challenge to Biology Approach

This approach always starts when a design’s problem is at hand, and when designers are seeking for the biological solution. This methodology works by the configuration of designing issues and goes back to nature for same types of solutions, thus, it is significant to the designers who are searching for inspiration in several design disciplines (URL 13).

In an example that is retrieved from biomimicry in industrial design, the Daimler Chrysler Company, that was investigating the great potential of bionics in its production, found a concept for its automotive Mercedes-Benz. Designers imitate the physical shape of Yellow Boxfish that is surprisingly aerodynamic to create a conceptual model according to company’s requirements (URL 41). “This Boxfish conserve its strength by moving while consuming the least possible amount of energy” (URL 41). This activity turned into an idea for design of this car. Furthermore, except for the biomimicry inspiration for aerodynamic form in this car, the structure and chassis of the car are also biomimetic and are emulated from the

tree growth pattern and the ability of division of pressure on the branches (Arnarson, 2011).

Figure 10. Daimler Chrysler bionic car that is inspired from boxfish and tree growth pattern (URL 17)

As the disadvantage of this approach, Pedersen Zari (2007) believes that mimic of forms and certain mechanical aspects of organisms like Boxfish, seems an easy process, but the other aspects such as chemical processes need scientific collaboration (Pedersen Zari, 2007).

2.1.1.1 Biology to Design Approach

Biology to design approach which is labeled as indirect method is based on the abstraction of principles of natural system functioning. In other words, this approach starts with cooperation of biologists and designers, but the basic idea of the project begins by biology specialists, natural sciences or related fields (Pedersen Zari, 2007).

As an example, in the wake of studying and analyzing the lotus flower, because of the remarkable self-cleaning property of its microscopic feature, the idea of new generation of surfaces was developed (Figure 11). The studying and investigating the capabilities of the leaves of lotus flowers led to invention of a new generation of surface materials in textiles, glasses, and building paints products. The Lotusan Paint is an innovated type of buildings paint's material with the same characteristics of the Lotus plant. The property of this product helps to lower the water usage and reduce the use of chemical cleaners (Arnarson, 2011; Pedersen Zari, 2007; El Zeiny, 2012).

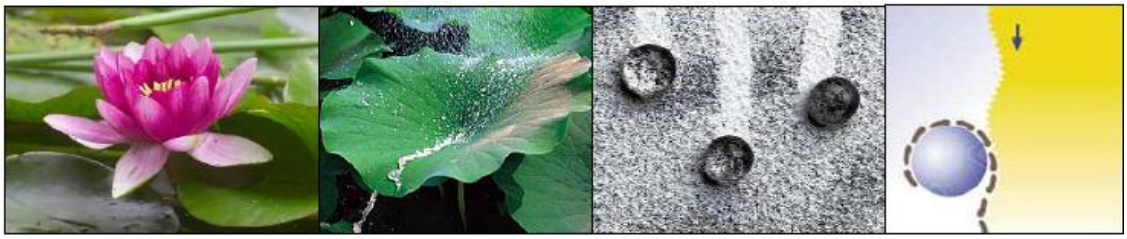


Figure 11. Lotus leaf inspired to create Lotusian paint (El Zeiny, 2012)

Therefore, the clever tactics in various natural species and existence of many similarities with our problems can pave the way for fundamental changes in design.

This approach focuses on solutions and already solved features of nature. Therefore, the potential of utilization of a particular science should be recognized and should be started after a basic research in biology; otherwise, there is not any ensuring of effectiveness and practicality of output (Vincent et al., 2006).

2.2.2 Provided Tools to Biomimicry Application

One of the major tools to applying biomimicry is named "Biomimicry Design Spiral" introduced by Carl Hastrichis. The "Design Spiral" as the main core of biomimicry process, at first was provided regarding to educational purpose, but today, many designers use it in their designs, based on the methodologies of biomimicry, (Figure 12). (Biomimicry Institute, 2014, Gamage & Hyde, 2012). Design spiral is defined to bring designer's sensibility to the biomimicry process and help to make it visually understandable for designers. This tool helps the innovative ideas found in nature to be utilized in design challenges through a clear process that includes: 1-Identify, 2-Interpret, 3-Discover, 4-Abstract, 5-Emulate and 6-Evaluate for "Challenge to Biology", and 1-Discover, 2-Abstract, 3-Brainstorm, 4-Emulate, 5-Evaluate for "Biology to Design". (Biomimicry Institute, 2014; Iouguina, 2013; Attia, 2015)

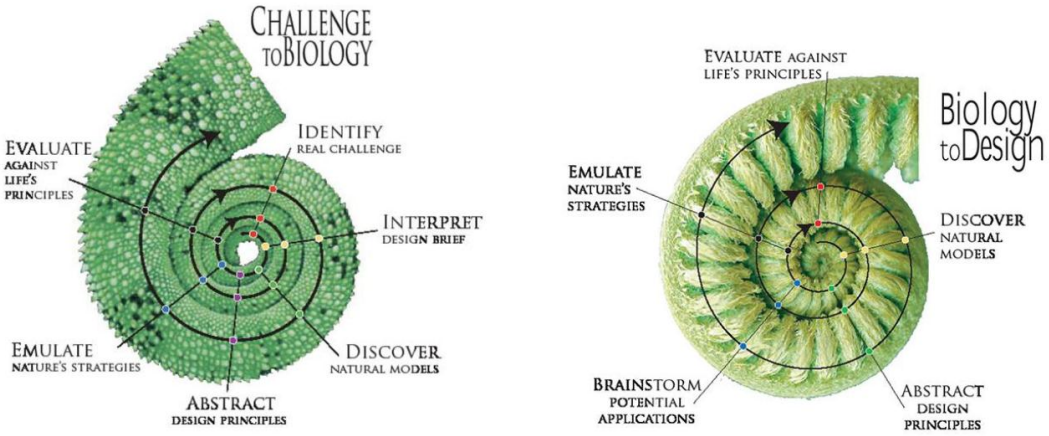


Figure 12. 'Design Spirals' tools proposed by the 'Biomimicry Institute' (The Biomimicry Institute, 2010)

After a while, the applying tools in biomimicry and its steps were further developed by "Biomimicry 3.8" organization in 2013, which is named "Biomimicry Thinking" (Figure 13) (URL 13).

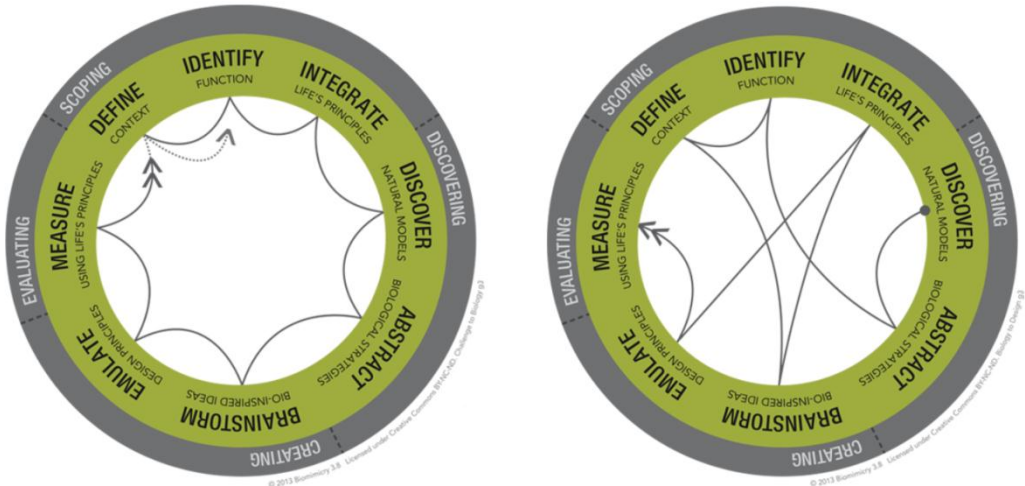


Figure 13. "Biomimicry Thinking" tools in two methodologies of biomimicry "Challenge to Biology" and "Biology to Design" (URL 13)

As can be seen in the simplified diagrams of these two processes (Figure 13) they include the same steps, but the sequences change as is shown by arrows. The 3.8 Webpage, states, "There are four areas in which a biomimicry lens provides the greatest value to the design process (independent of the discipline in which it is

integrated): scoping, discovering, creating, and evaluating. Following the specific steps within each phase helps ensure the successful integration of life's strategies into human designs" (URL 13).

El Zeiny (2012) explains these steps in different frames to be used in interior architecture. The below figures, "Problem based approach" and "solution based approach", (Figure 14 & 15) have different names, but these models follow the similar ways as same as the previous methodologies' steps. Also, the below types of biomimicry methodologies are used in industrial design with different names: "Problem-Driven" and "Solution-Driven" (Helms, Vattam, & Goel, 2009).

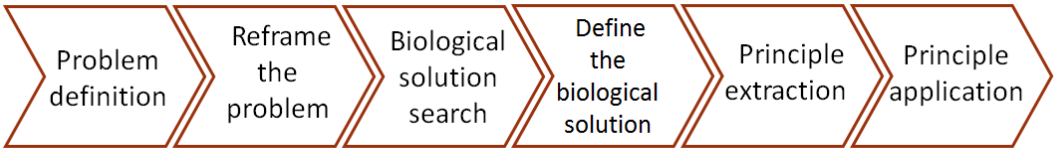


Figure 14. "Challenge to Biology" approach, redefined by El Zeiny in "Problem based approach" (El Zeiny 2012)

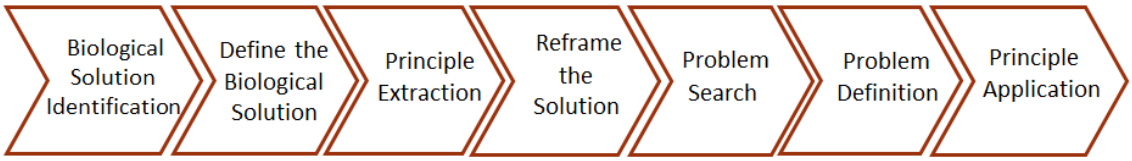


Figure 15. "Biology to Design" methodology, redefined by El Zeiny in "Solution based approach" (El Zeiny 2012)

2.2.2.1 Steps of Applying in Design Process

This section discusses what designers should do in each step of biomimicry process. For this purpose, the understandable and developed tools in biomimicry are chosen to explain this part. As most of the steps of two methodologies in "Biomimicry

thinking's tool" (figure 13) are the same, and only the sequences change, thus, they are suitable to be explained in this part.

Define Context

Designers in this step should specify the design problem and its operating conditions. They should define problem by asking questions such as: How nature can solve this problem? Where is the problem and who is involved with the challenge? Where will the solution be applied? Who will be involved with the solution? (URL 37).

Identify the Function

Designers in this step should identify the real challenges at hand (Korecki, 2008). It can begin with deconstructing the problem to the functions, and designers in this step should think about the design challenges from various angles (URL 35), and "determine what key function(s) must be performed and what is needed to be done?" (URL 37).

Integrate Life's Principles

In this step, designers must commit to incorporate Life's Principles into the design requirements, and make sure that the identified ideas can incorporate with Life's Principles into the solution (URL 37).

Discover Natural Models

In this step, designers should "find organisms or ecosystems that have evolved strategies to solve the needed function(s)" (URL 37).

This stage is a significant step, because the best natural models should be found to solve the problem in this process. There are several approaches suggested in this step. The first one is research in literatures, and textbooks about the subject. The second is collaborating with biologists or other specialists that "their expertise can greatly enhance the quality and quantity of organisms identified" (Korecki, 2008, p. 67). The third is observation through walking in nature and observe the organisms and ecosystems that might be answer in what you want to do.

Abstract Biological Strategies/ Translate

In this step, designers should determine the mechanism behind the selected natural ideas and then translate life principles into design parameters through making a connection between design and problem in the natural world (URL 37). They should ask how nature could find efficient solutions and successful patterns for this function at the earliest stages of the design.

For example in architectural design, building analysis includes; habitat, climate conditions, social conditions, temporal conditions (Mansour, 2010). After that, designers should find organisms with the similar problem, and find out that what the organisms can do, and then find the most relevant of them to the design strategy (URL 36 & Mansour, 2010). Korecki (2008) suggests, this could be useful for designers in this level to ask initially, "how does nature do this? "How does nature not do this? These questions can be expanded by placing conditions under the achieved functions. For instance, designers might ask, how does nature achieve this function under these specific climatic, environment, social, or habitat conditions? (Korecki, 2008, p. 66).

Brainstorm

As it is obvious from its name, designers in this step should think of ideas that how they can be matched with design principles to solve the design problems. The brainstorming step allows concepts and solutions to be feasible as an idea to be used in design (URL 37). In addition, the brainstorming process has generally several techniques that knowing them can be helpful for designers in this step.

Emulate

In this step, a designer should develop a design concept, from the best-brainstormed ideas. This concept is in hand and could be applied in several levels in biomimicry (URL 37 & 35). Section 2.3 will describe these levels in detail and suggests to designers a framework for application of biomimicry to design (Figure 9).

Measure using Life's Principles/ Evaluate

In this crucial step, designers should measure the project in terms of sustainable principles. If the driven mimicked design not accord with these principles, this steps should be repeated from the beginning so that it eventually be evaluated with principles of nature (URL 37 & 35). Different approaches can be used to evaluate the design outcome according to sustainable principles. Study the Life's principle chart, (Figure 9) is one way, and the other way is to accord the design outcomes to the standards provided by international sustainability certificate organizations such as 'LCA', 'LEED certificate' and 'IEQ Leeds certificate' (Mansour, 2010).

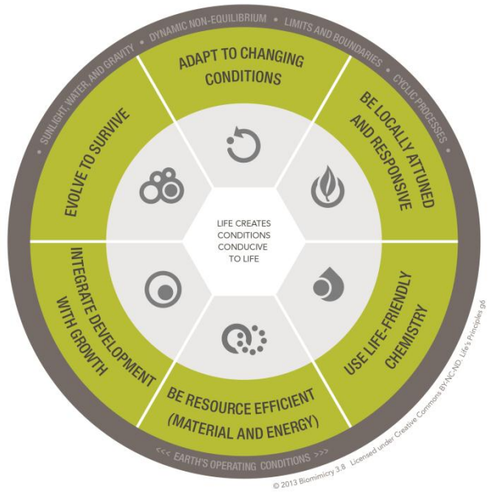
Although in architecture and interior architecture, mimicking the physical forms and patterns in nature can be easily done, but this analogical approach lacks the essence of biomimicry design that is learning from how nature works and solves the life

problem in a sustainable way. To be able to do real biomimicry design, designers need to benefit from this approach with the company of biologists or accessing potential solutions in biological research; otherwise, many of concepts remain at a low level of inspiration. Therefore, collaboration with biologists and participate them in the discovery phase to provide in-depth biological knowledge in design is recommended in this stage (URL 37 & 35). Figure 16 summarizes all the above-mentioned information related to biomimicry design steps and tools in a compact graphic way.

1. Define Context

2. Identify Function

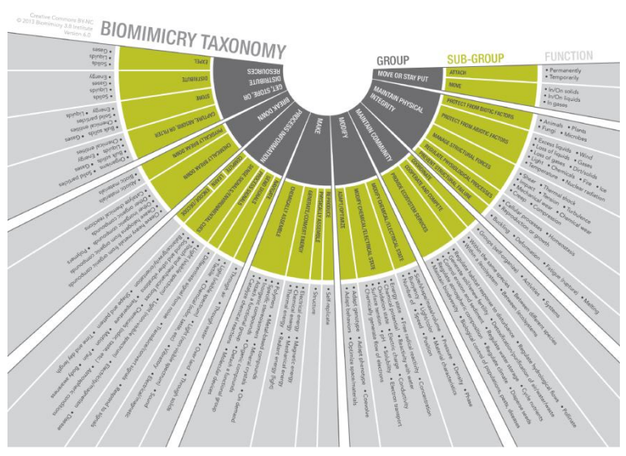
3. Integrate Life Principles



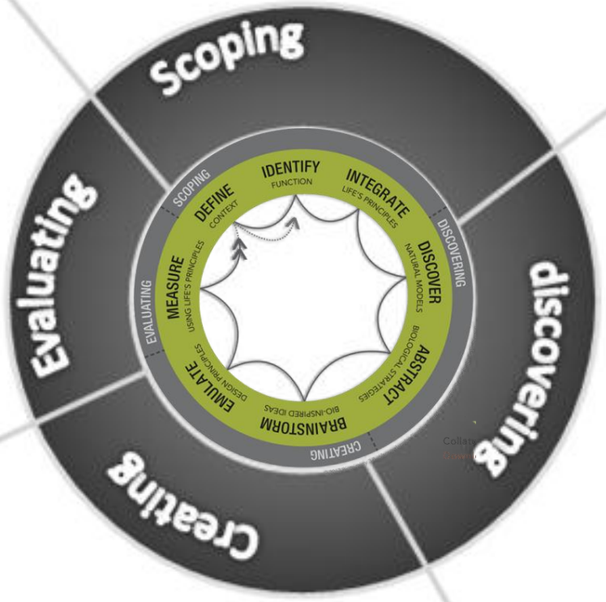
4. Discover Natural Models

Interdisciplinary approach

AskNature Weblog



5. Abstract Biological Strategies



6. Brainstorm Bio Inspired Ideas

7. Emulate Design Principles

8. Measure Using Life Principles

Figure 16. Biomimicry design phases, steps and tools in a compact shown graphically

2.3 Levels of Biomimicry

Biomimicry has three levels that can be applied to design problems. These levels are regularly given as organisms, behaviors and ecosystems (Benyus, 1997, Pedersen Zari, 2007, Biomimicry 3.8, 2013; Bakırlıoğlu, 2012; El Ahmar, 2011; El Zeiny, 2012; Mansour, 2010; Gamage & Hyde, 2012).

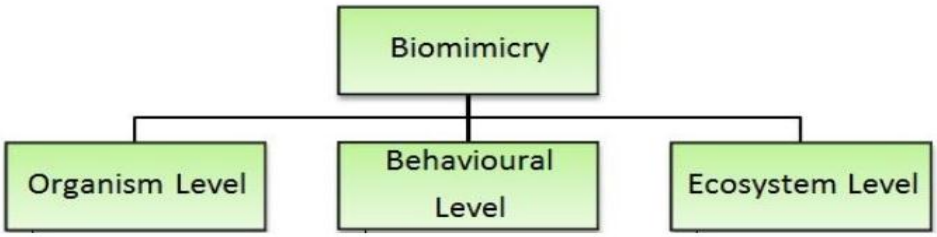


Figure 17. Levels of biomimicry (Anous, 2015)

These three levels are "identified as necessary for a full emulation of nature in biomimicry" (Benyus, 2008, p. 40). Gamage (2012) recognizes them as "shapes of living beings, manufacturing processes operating in those living beings as well as interactions between species and lastly, the global functioning of natural ecosystems" (Gamage & Hyde, 2012, p. 229). Benyus (1997) believes, biomimicry has proper solutions for solving human problems through the copy of nature in these three levels (Benyus, 1997). In this section, after the definition of each level, the implemented examples around the world will be introduced one by one. These architectural examples have been selected in a manner that the interior architecture aspects can be identified and analyzed.

2.3.1 Organisms Level

As noted earlier, organisms have withstood and adapted themselves to the environment after millions of years of evolution. Any organism that exists on the earth can be a valuable source of design. At this level, designers engage with variety

of information sources, which are produced through this evolution. Hence, understanding how the organisms interact in this level of biomimicry, gives us the opportunity to mimic a single organism or the whole system of nature.

An example is a "Bumpy Body Beetle" in desert that became an inspiration for an idea to design a fog catcher system for the Hydrological Center of Namibia University (Figure 18) (URL 25).

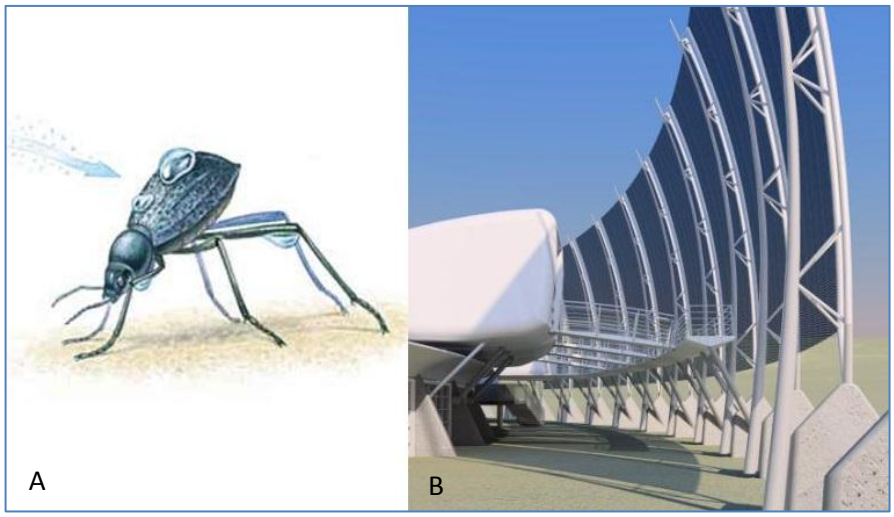


Figure 18. A: The Namibian Beetle (URL 8)
B: Hydrological Center at Namibia University (URL 25)

This intelligent beetle captures water droplets with the help of its hydrophilic shell in the desert with less than half an inch of rainfall. When droplets are stacked to each other and become heavy, they lead it to their mouth. A student at Oxford University developed a system to catch water to be used in this center based on this idea. This center is located in the arid coastal region, and by this invention can collect all the water they need through the regional fog in the area (URL 8 & 25). Manonmollard in the Technology and Architecture weblog (2013) says, "A nylon mesh sail collects the fog as it rolls in. When mesh becomes saturated, gravity feeds the water into an

underground tank, where it joins pumped-in seawater that has been desalinated using photovoltaic panels. This method captures 10 times more water than existing fog catching nets" (Figure 19) (URL 39).

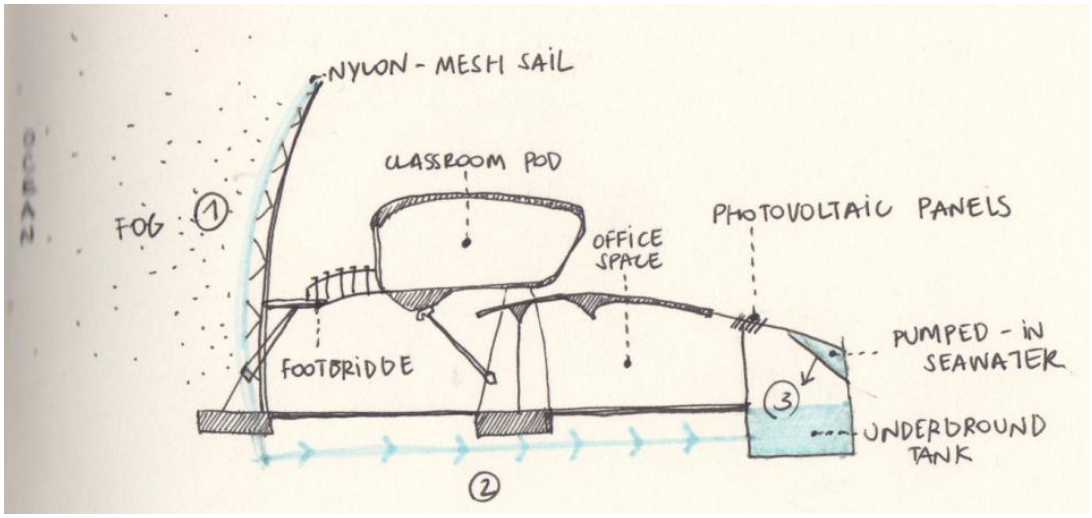


Figure 19. A section of the fog catcher system (URL 39)

This idea is quickly developing to be used in any place that needs water (URL 24 & 25).

Unfortunately, in interior architecture, most of the examples in this level are seen in imitating of forms, rather than mimicking of forms. Nature has much potential to mimic in technological elements and objects in this level. Therefore, because of little biological knowledge about the organism, the process may remain at the basic stage of design. On the other hand, this level tends to be mimicking of a single item rather than a whole system, thus has potential to be at the low level of sustainability (Pedersen Zari, 2007, El Ahmar, 2011).

2.3.2 Behaviors Level

This level of biomimicry considers the well-adapted behaviors and the relationships patterns between organisms or species. In the behavior level of biomimicry, it is

possible to simulate the relationships of organisms with other species, or relationships between living organisms in daily life, single and group behaviors in a colony (Pedersen Zari, 2007).

One of the well-known examples of biomimicry in this level is the design of a shopping center with green and sustainable ideas, which is inspired by the behavior of African termites in constructing their mound. This building designed by Mick Pearce, located in Harare, Zimbabwe is exactly modeled from the termite mounds' cooling system (Figure 20). Because of the high activity, inside the mounds need to be cool. For this purpose, these insects embed some channels at the lowest part of the mound to help sucking the fresh air inside and let hot air go out with chimneys at the highest part of the mound. This air circulation system is used for cooling a building in the summer days with minimum usage of energy in the hot days in Harare. Therefore, the energy payment in this grand commercial center is 20% less than other similar buildings, thus, the building saves 3.5 million dollars for the owners during a year (URL 25; Rabbani Rankouhi, 2012; Doan 2012).

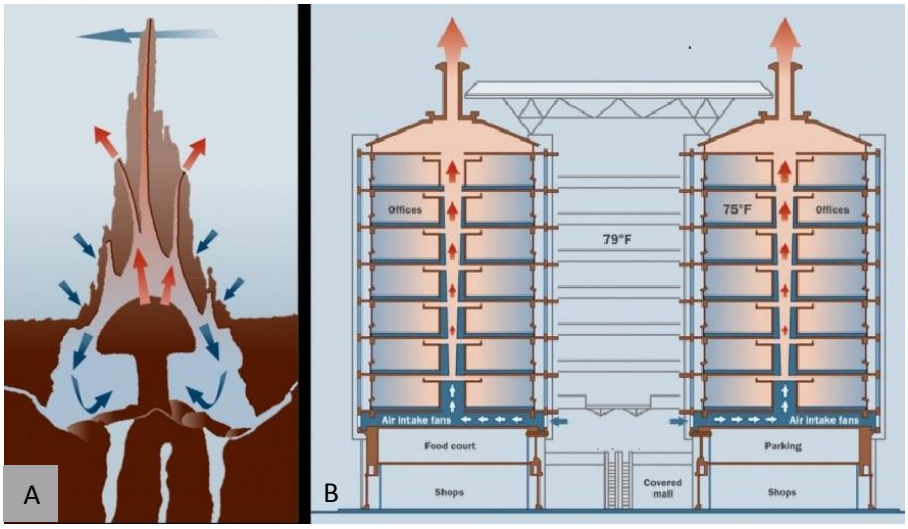


Figure 20. A. Circulation Channels embedded in termites mounds.
B. A section from Eastgate Center Building (URL 39)

On the other hand, understanding the valuable behaviors that how species in nature can change their surroundings while making more capacity for life of other species in the natural system, can help in adjusting our habitats while providing living environment for the other species. An example is corals and its living colonies under the sea that many other species such as fish, invertebrates, algae and microorganisms make their homes on and around this reef (URL 22). Therefore, these behavioral ideas, which exist in nature, can increase the nutrient cycling, and help to create mutually beneficial connections among species and us (El Ahmar, 2011; Doan, 2012).

2.3.3 Ecosystems Level

Mimicking the ecosystem is an integral part of biomimicry (Benyus, 1997). Mimicking of the ecosystem is often used in grand projects, where instead of more financial profits; the idea is to defense the nature and ecosystem. The aim of mimicking ecosystem is to support a movement towards a green life to use in the future (Maglic, 2012). Pedersen Zari (2007) believes that the application of ecosystem level in architecture needs to involve the knowledge of other disciplines in design process. She explains:

> "That a greater understanding of ecology and systems design is required on the part of the design team is implicit. Also required would be increased collaboration between disciplines that traditionally seldom work together such as architecture, biology and ecology. Such an approach challenges conventional architectural design thinking, particularly the typical boundaries of a building site and time scales a design may operate in" (Zari, 2007, p. 7).

On the other hand, the most crucial advantages of the ecosystem level can be the environmental performance and its effect on building design. Biomimicry design based on ecosystem should be evaluated by ecosystem principles (El Ahmar, 2011).

Research conducted by Pedersen Zari (2007) explains that, ecosystems depend on life principles, thus, the buildings designs in this level should also depend on these life principles. Figure 21, summarizes the functioning principles of ecosystem that can be used by designers in the design process.

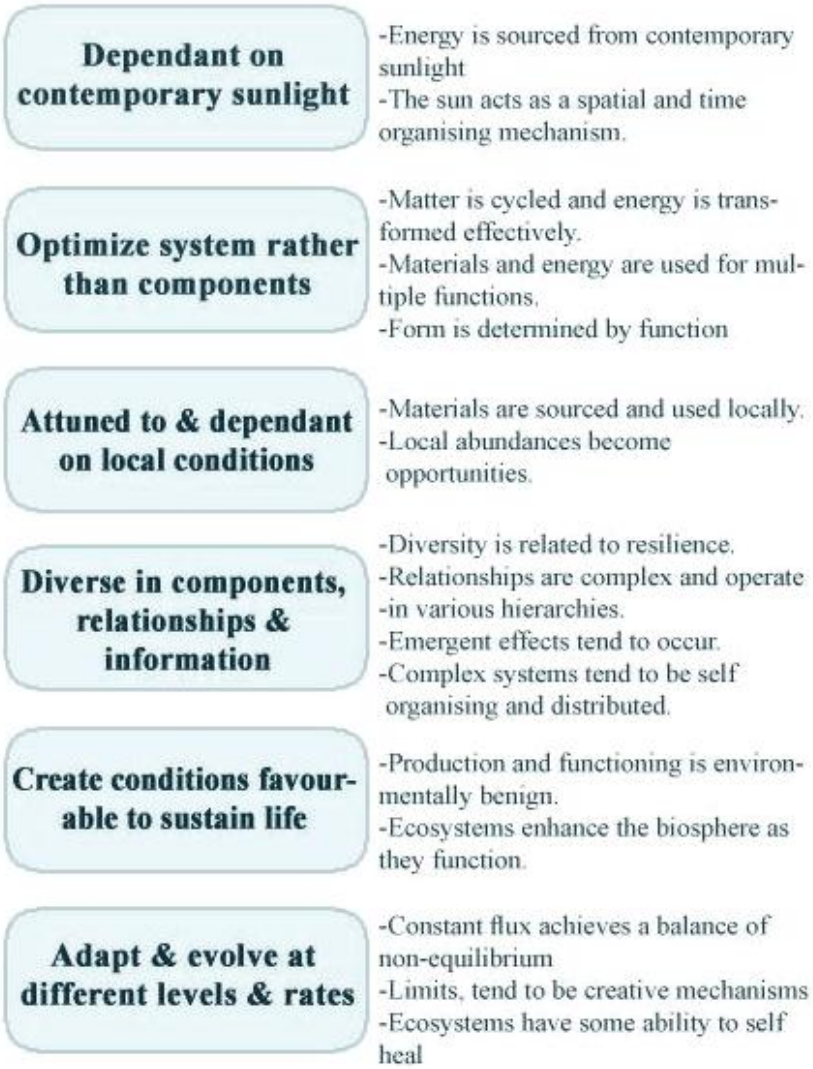


Figure 21. Ecosystem principles (El Ahmar, 2011)

Zari (2007) states that, "mimicking of general ecosystem principles should be incorporated into the design and be used as an evaluative tool throughout the design process" (Pedersen Zari, 2007, p. 7).

Therefore, above requirements should be fulfilled, to bring sustainable quality to design. Biomimicry in building design is not only about adapting the design from nature but also about considering natural practices in issues such as heating and cooling system, ventilation and sunlight usage (Rao, 2014). Figure 22 and 23 show an example of a building (Earthship) designed following all principles of biomimicry in ecosystem level.

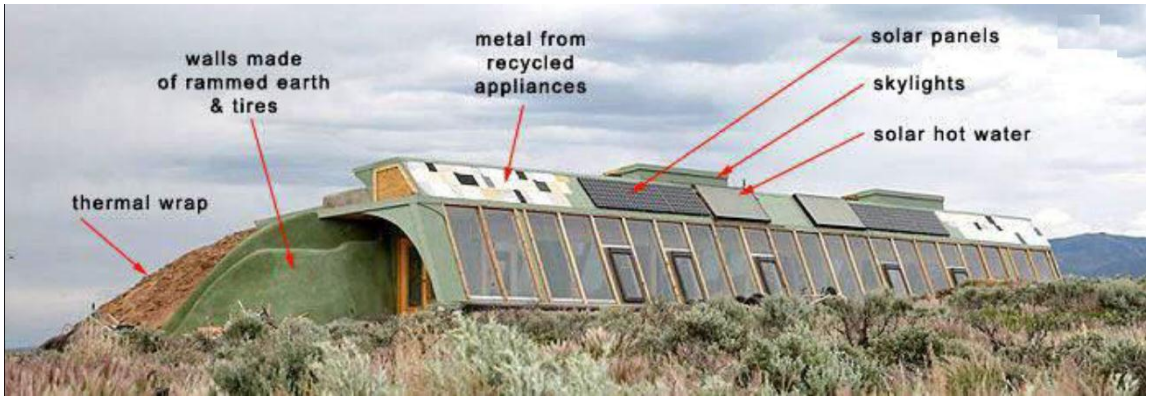


Figure 22. The Earthship as a sustainable home, which is designed to integrate with nature as an example of biomimicry in the Ecosystem level (Anous, 2015)


Figure 23. The interior botanical and photovoltaic solar cells of Earthship (Anous, 2015)

This case is designed to integrate with nature based on six natural design principles:

(1) Use of recycled and local materials for construction such as sand bags, tiers, adobe.

(2) Cooling and heating system from the natural resources like sun and earth.

(3) Harvesting rainwater on the roof and catching dew and fog through mimicking the Namibian beetle bumpy body.

(4) Renewable energy created by photovoltaic cells and wind generator that also can be stored in batteries and supplied to electrical automated outlets.

(5) Collecting the gray water from bathing, and use it after second filtering for botanical cells. Also in this building, the third filtered water is used in the toilet flash and the fourth filtered water is used for the exterior botanical. The water for washing is also separated from black water.

(6) Food production is done by inside and outside botanical planters (Mansour, 2010).

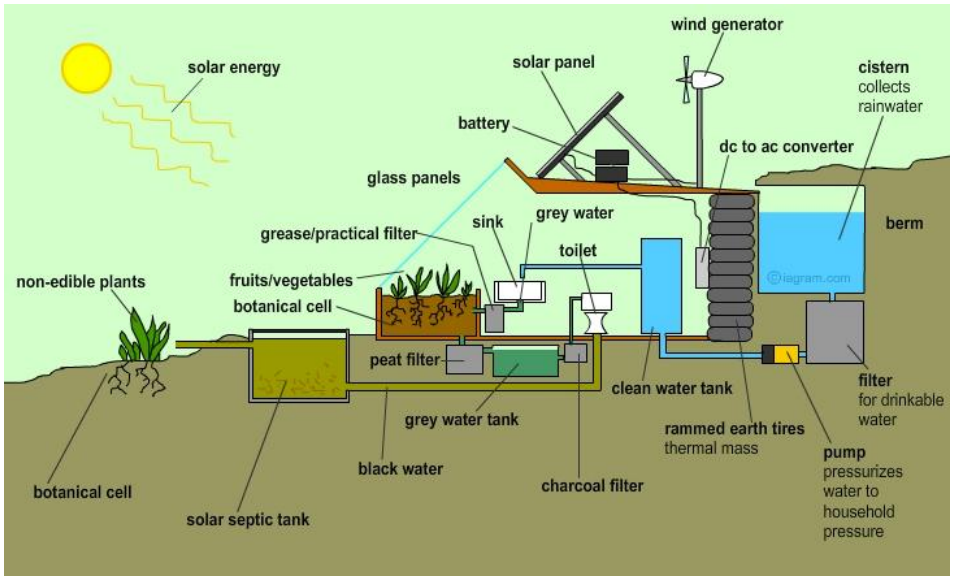


Figure 24. A section of Earthship (URL 20)

Therefore, in each level of biomimicry, nature is a reachable source of inspiration, and this is a good chance that these mechanisms be learned to be used in the future projects in the interior architecture. However, Maglic (2012) believes, “not all projects can just take any element of nature and transform it into solving human

needs directly as is. This is a common criticism against Biomimicry and how it is used to solve human demands" (Maglic, 2012, p. 29).

2.3.3 Additional Levels in Biomimicry

Pedersen Zari in the field of architecture suggests five additional levels that can be equally applied within the above-mentioned three main levels. These are as follow: what it looks like, (form), what is made out of (materials), how it is made (construction), how it works (process) or what it is able to do (function) (Pedersen Zari cited in El Zeiny, 2012). Pursuing Benyus' research, Pedersen Zari, has submitted this model from architectural design point of view. Her effort led to creating a framework to explain the application of biomimicry according to different levels and five additional sublevels of design in architecture (Figure 25).

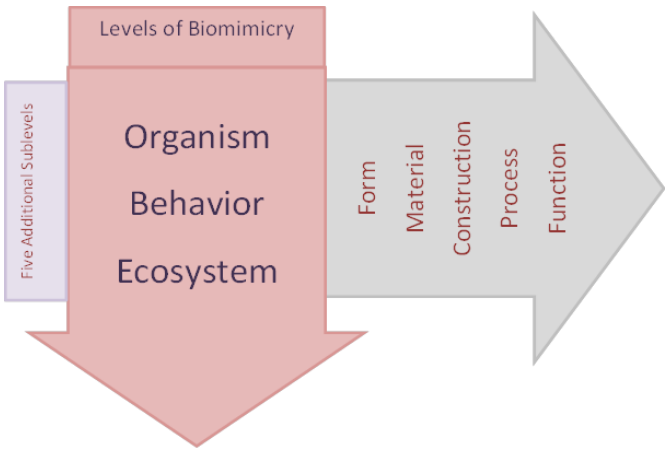


Figure 25. Additional levels of biomimicry (El Zeiny, 2012)

Furthermore, this attempt clarifies the potential of using biomimicry as a tool to increase the regenerative capacity of the built environment and can be used by design students as a methodology for improving the sustainability in design as an effective approach (Gamage & Hyde, 2012). Figure 26, takes examples from clever termites in nature and draws attention to the various aspects of the insects in each level of

biomimicry. Pedersen Zari (2007) recommended in her article such a study as a resource for students and designers who want to refer to each level.

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

Figure 26. Framework for the application of biomimicry (Pedersen Zari, 2007)

This framework is applicable in both biomimicry approaches "Challenge to Biology" and "Biology to Design". Next section explains how these additional levels can be applied in interior architecture.

2.4 Biomimicry in Interior Architecture

Today, several fields such as architecture, medicine, engineering, art, industrial design, etc. are benefiting from biomimicry as a design method (Tavsana & Sonmez, 2015). Biomimicry is spreading widely throughout the world, and this method is

starting to find its place and growing popularity in interior architecture too. Since, interior architecture field has multiple dimensions in design such as objects and elements, functions, spaces etc. spreading biomimicry can help to solve design challenges in this field too. Next section will introduce some successful examples of biomimicry that are applied in interior architecture as a sustainable idea.

2.4.1 Examples of Biomimicry in Interior Space Related Designs

- **House Design Inspired from Nautilus Shell**

This unconventional house located in Mexico City is designed by Javier Senosiain for a family with two children (Figure 27). The design of the house is inspired from the nautilus shell. Characteristic of this villa is that it has curved spaces everywhere such as spiral stairs, bedrooms and toilets, as well as many details in finishing and existing furniture, such as in the stained glass and skylights. The interior of this building has been designed with odd forms that are connected to each other with a ramp. The interior is also filled with plants and organic patterns in a stony path (URL23).

The spiral shape and curved walls of this home are constructed with a sprayable concrete (Grancrete), because the shell structure, is rigid and has not any column. In addition, the structure by using this material is more earthquake-friendly and stronger than concrete. This project is an example of using biomimicry inspiration from natural forms and implementing it in living spaces (El Zeiny, 2012; Zari, 2007).

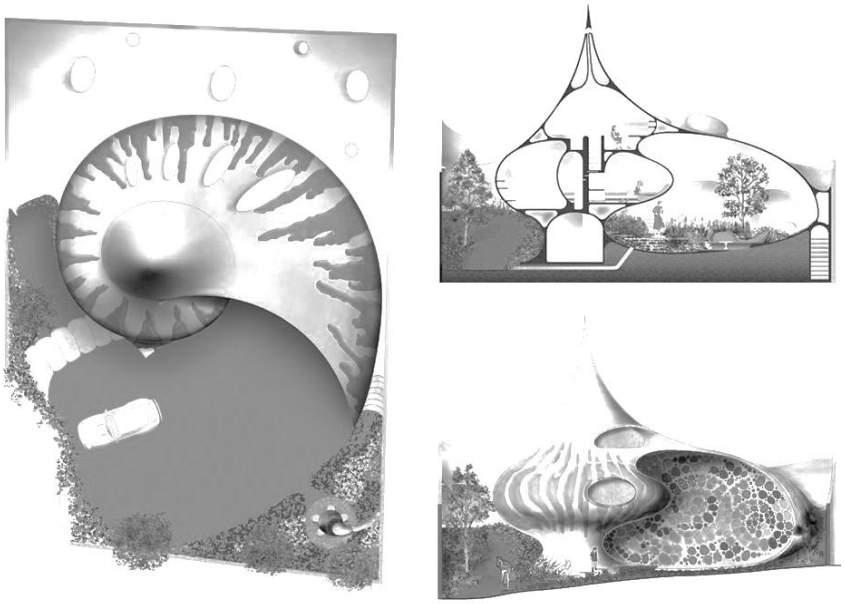


Figure 27. Natural forms inspired from Nautilus Shell (URL 23)

- **Shelter Design Inspired from Pangolin Skin**

The innovative ideas that were formed in Nicholas Grimshaw & Partners' mind for the semi-open terminal of “Waterloo International Airport in Ontario” is one of the important examples of organism level of biomimicry. An animal named “Pangolin” with flexible scales on its skin has helped to develop a design to set the air pressure of "departure" part of this terminal, (Figure 28). Train’s arrival in the terminal with high pressure needed a flexible structure to be able to direct the air outside. Imitation of the flexible arrangement of the skin of this animal responded to designers’ need for this challenge (URL 46).

Figure 28. Innovative function inspired of Pangolin skin (URL 46)

- **Innovative Façade Inspired from Cactus**

The project named MMAA Tower that has many similarities to cactus is designed by Bangkok-based Aesthetics Architects for the Ministry of Agriculture of Qatar (Figure 29). Designers utilized a fascinating idea based on the shading properties of the cactus' spines, to design an elegant facade in this building. The sunshades on this building have the ability to move automatically up and down, according to interior temperature, to regulate the amount of sunlight in to the space. Maglic (2012) states that "this innovative solution allows this building to lower the size and amount of artificial cooling necessary for the building to operate properly as well as providing a sustainable solution that is aesthetically pleasing" (Maglic, 2012, p. 17) .

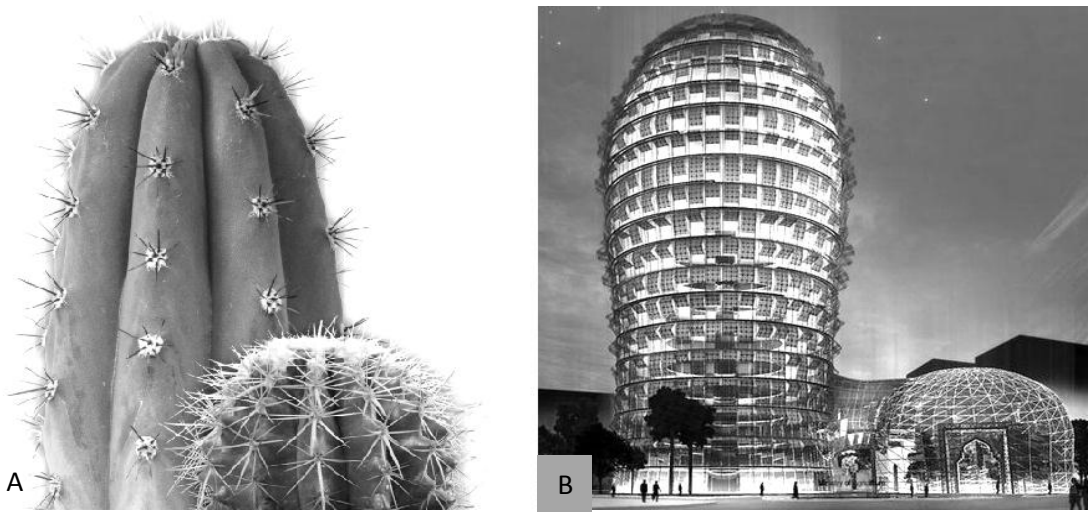


Figure 29. A. Two cactuses and its spines (URL 38)
B. MMAA Building (URL 32)

On the other hand, this building is situated in a desert area, with average rainfall of 3.2 inch per year. Therefore, the innovative idea of "Cactus's activities at night" came in the minds of designers to design a smart system for the botanical garden under the dome at the highest part of this tower. "This idea is similar to how a cactus chooses to perform transpiration at night rather during the day in order to retain

water" (URL 30). By using this system, building can provide the needed water to use in the garden. Moreover, this building is equipped with robotic navigation and smart detection of water pollution (URL 30).

- **Responsive Structure Inspired of Conifer Cone**

FAZ Pavilion located in Frankfurt city is based on the biomimicry practice and the idea of how conifer cone closes and opens (Figure 30). The structure of the surface of this pavilion is as a real conifer cone and it can response to the climate change passively. The smart shape of pavilion opens and closes automatically without any extra mechanical or electronic control by absorbing the moisture existing in the air.

Figure 30. A. Responsive Structure of FAZ Pavilion. (URL 21)
B. Conifer Cone (URL 33)

In addition, this structure is located on a site in the center of the city, which is a popular place in summer time. Hence, to create a comfortable place for the people, this responsive structure with its sensors that are sensitive to sunlight can regulate the surface and the whole vents open in sunny days. In rainy days, vents are closed and the interior of this public space keeps its normal humidity. Therefore, this low-cost technology can be considered more in future, particularly for the semi-open structures that are located in humid climates (URL 5).

- **Bullitt Building Inspired by Living Process in Forests**

Architect Miller Hull creates this building located on Capitol Hill in Seattle, (Figure 31). The project is inspired from the living process of Douglas fir forests in Western North America. This building also like the amazing ecosystem of the forest, can consume water and save its usable energy without the need for any source of energy (Lotter, 2014).

Figure 31. The Bullitt building inspired by living process in forest (URL 18)

This building has 600 solar panels, which generate all the energy needs in a year. This center also has a cistern, which provides all the water needs from rain to be used for the building. Also, the waste water can be regenerated for toilet systems, and a garden (Werner, 2013). This innovative building design achieved the greenest commercial building in 2013 in United States. Robert Peña, a consultant in this project (2013) says, "Center is 80 percent more efficient than a typical commercial structure. And building more efficient spaces has the potential not only to address many of America's energy issues but also to blunt the impacts of climate change" (Peña cited in Werner, 2013).

- **Sustainable Carpet Tile Inspired by Forest Floor**

Oakey group in the Interface Floor Company designed an innovative floor system with biomimicry approach to be used in interior design. The focus of this company is on two factors of beauty and sustainable production. Designers in this firm produced floor carpets with natural beauty that are inspired by the colors and patterns that could be seen on the forest floor and rivers' bed (Figure 32) (Larson, 2011).

Figure 32. Interface floor inspired by from natural pattern (URL 27 & 44)

The colorful variety of this product creates "a harmonious whole and eliminates the need to match specific dyes or install tiles in a particular direction" (Larson, 2011, p. 321), which leads to increased flexibility, quick installation, easy maintenance and repair. Therefore, this product is one of the interesting examples of mimic of form and beauty of nature that has been used in interior design.

- **Modular Shelve System Inspired from Honeycomb's Hexagonal Cells**

This modular shelf system is designed by Jack Godfrey Wood and Tom Ballhatchet. They were inspired by honeycomb's hexagonal cells that are joined together to form a hive. These hexagonal shapes can be produced in any number and can join in any way based on a single geometric unit (URL 29).

Figure 33. Modular shelve system (URL 38)

These modular shelves are made of expanded polypropylene that is lightweight, 100% recyclable and nontoxic. Figure 33 shows this functional object, which can be assembled easily and can be used as a temporary seating element or transport box when it is dismantled (URL 29).

- **A Chair Inspired by the Cellular Structures in Nature**

A soft seating element designed by Lilian van Daal (2014) inspired by the cellular structures found in nature (Figure 34). The consumed material to use in this design is polyamide, and distributed in a way to enabling some parts to be soft and the structural parts to be rigid. This idea is a new concept to make the producing

furniture with more sustainable features using 3D printing. The production process, and also recycling process of typical chairs and sofas are normally far from sustainable, because they are made from various materials and prepared for assembly in different factories. With developing this idea and using 3D printer technology, we can reproduce many complex structures in nature that cannot be produced with common production techniques. Using this method, furniture and design elements in interior architecture can be created from one material in one place or factory, and the pollution caused by transportation of several materials to use in furniture can be minimized (URL 34).

Figure 34. A chair inspired by the cellular structures in nature (URL 34)

Ultimately, the usage of nature and its ideas in design are considered as a biomimicry project only if it has the potential to create a useful tool for people (Mueller, 2008). Based on these examples, it can be seen that biomimicry is an emergent practical framework for the interior architecture field. Since, this sustainable approach

continues to grow in the interior design field too, it would be wise to integrate the concepts of biomimicry in design education to recognize the benefits of using nature as a source of inspiration in design of living places. Next chapter will discuss the intersection of biomimicry and interior architecture education to investigate about possibility of teaching this method to interior architecture students.

Chapter3

BIOMIMICRY IN INTERIOR DESIGN EDUCATION

3.1 Overview

Understanding how nature works and learning how to have a mimicked design according to principles in natural systems can be a significant aid in design education in this century. “Imagine if students of design knew how to operate renewable energy and eliminate the concept of waste by making every waste product a raw material or nutrient for another species or activity or return it to the cycles of nature” (Cortese, 2003, p. 16). As nature can be a great educator to learn from, teaching biomimicry as a tool to transfer the inspirational ideas and strategies in nature to building systems, can be beneficial in design education. This chapter tries to review the efforts in biomimicry education and to describe the challenges and opportunities for educators in integrating biomimicry. In addition, examples of studio experiments are presented to find out how this method can be of use in studio especially in interior architecture studio.

After emerging bio inspiration methods (BID) in the last fifty years, the necessity of using biomimicry is proposed in education. But, the question is, how indeed the education can accept them? Some believe that a substantial change is needed to accept them in design education. Capri (2010) states that:

> "To create a dialog between design and nature our design epistemology requires a fundamental change. Not only our design praxis but also our design pedagogy is still based on 19th Century Beconian principles within which the notion of domination over nature constitutes the foundational thought process

> ... In order to respond to the current disconnect between architectural design and Nature, we need to re- evaluate our design pedagogy through the filter of sustainability design pedagogy" (Carpi & Brebbia, 2010, p. 548).

Parallel to this, DeKay (1996) also recommends, “To educate designers for ecologically and socially responsible practice, design schools are needed to be radically redesigned in their structure, content, and methods” (DeKay, 1996, P. 1). Yeler (2014) believes that, a student can be aware of biological expressions in design knowledge “if education programs are revised in a way that enables the student to comprehend how these events occur in nature” (Yeler, 2014, p. 408). Al Ajlouni (2011) believes that, this transition to be achieved, should be an ongoing learning process (Al Ajlouni, 2011).

Nevertheless, the interest in bio-inspired design in education is accelerating, and biomimicry as one of the well-known disciplines among them is developing day-by-day (URL 10). Although, biomimicry has been recently introduced in education, but several institutes, colleges and universities have integrated biomimicry in their programs. There are numerous programs comprised of researches, courses, workshops, labs, and exhibitions being held in different education levels around the world. Biomimicry Institute, which is the pioneer in this regard, offers many educational programs, workshops and courses for professionals, related to all fields of design and engineering (URL 14). Also, several courses are compiled and offered to students as online and non-online programs such as “Introduction to Biomimicry”, “Biomimicry Thinking”, “Life’s Principles”, “Essentials of Biomimicry”, “Biology Taught Functionally” and “Biomimicry and Design” by several universities and institutes around the world (URL 11). In higher levels, several universities PhD and Master programs are regarding biomimicry and open research opportunities to

students such as University of Akron, Arizona State University and Berkeley University. Among them, some universities are employing biomimicry in different levels and courses of architecture education, such as Southern California Institute of Architecture, Ontario College of Art & Design, Architecture Department of Universidad Iberoamericana, Stanford University, University of Illinois, University of Minnesota (Angne, 2012; Tyler, 2012).

3.2 Biomimicry as an Educational Method in Interior Architecture

Despite these attempts in design education, there are very few studies about application of biomimicry as an educational method in interior architecture. On the other hand, numbers of published accounts on teaching practices related to application of biomimicry in design studios are hard to come-by (Gamage, 2012).

There may be several reasons behind this gap. One possible reason, can be that biomimicry approach is still very much new in the field of interior architecture. On the other hand, one of the major concerns is that biomimicry like other methods in bio-inspired design has some inherent complexities in its process. Wilson (2008) believes that these difficulties include: "(1) the large analogical distance, (2) lack of cross-domain knowledge, and (3) identification of relevant strategies" (Wilson, 2008, p. 7). These three issues might be the main reasons that biomimicry remains at the experimental stage in design studio and consequently cannot be spread widely in interior architecture education.

Gamage (2012) believes that although, the application of bio-inspired methods have hardly been articulated, among them, biomimicry is one of the applicable and appropriate translation system in architectural design studio. She believes that by

developing analytical aid tools in mimicking process such as “Design Spiral”, biomimicry tries to overcome these difficulties (Gamage, 2012). Given its complexity, the transition toward sustainable thinking does not follow a linear evolution, but rather it, should be an ongoing learning process that makes experimentation, flexibility and adaptability crucial to success.

In this regards, biological information should be expressed and be available in common language for students, thus, this study will introduce two additional strategies to solve these difficulties, which are exist in biomimicry education.

- Interdisciplinary Approach
- AskNature Tool

Following sections will introduce these two approaches in biomimicry education by bringing examples.

3.3 Importance of Interdisciplinary Approach

Human knowledge is developing continuously. Although beneficial, but this cycle of knowledge has increased the complexity of design work. Interdisciplinary collaboration is an alternative method to solve problems of complexity in design (Korecki, 2008). Thompson Klein (2003) defines this method as “a label for a variety of interactions that aim to integrate concepts, methods, data, or epistemology of multiple disciplines around a particular question, theme, problem, or idea” (Klein quoted in Caforio, 2006, p. 17). An interdisciplinary analysis by Seipel (2004) describes it as “drawing on the specialized knowledge, concepts, or tools of academic disciplines and integrating these pieces to create new knowledge or deeper understanding” (Seipel cited in Korecki, 2008, p.31). Designers with the help of biologists can overcome the biomimicry complexities in any disciplines such as

interior architecture (Scorza & Cavalheiro, 2010; Rossin, 2010; Angne, 2012). Carpi (2010) believes this technique is an essential approach to achieve high levels of environmental standards in the buildings and related technologies (Carpi & Brebbia, 2010). Benyus thinks that a "biomimetic revolution will happen in the following years if this learning process is popularized in other disciplines" (Benyus quoted in Tavsana & Sonmez, 2015, p. 2287).

Successful translation in biomimicry designs requires a new way of thinking about the relationship between design education and biology science. As the students need biological knowledge in design process when using biomimicry, being an interdisciplinary team of instructors to identify and apply biological knowledge in the studio can be a crucial need.

As an example, this part describes the experience of a groundbreaking approach in biomimicry education of a major university in United States. Arizona State University started to develop a curriculum for applying biomimicry in 2008. Biomimicry requires a willingness to work in the unfamiliar territory of biology in the various fields of this university, such as design, engineering and business faculty. Despite the hurdles, they initiate to launch an initiative academic year in 2008 that includes Curriculum development in biomimicry, staff and faculty training in biomimicry, the hiring of graduate teaching assistants in biology, establishment of classrooms, workshops and meetings for students led by biologist and engineers from the biomimicry institute. After a trial education year in 2008-2009 in industrial design, results show that they were successful in deployment of biomimicry within product design studio (Smith & Fisher, 2011). One of the hires in team (2010) cited:

> “The bedrock of our biomimicry curriculum is our collaboration with biologists. Doctoral students from ASU's School of Life Sciences helped to design the biomimicry curricula, deliver lectures, conduct classroom exercises, negotiate the scientific literature with students, and provide studio critiques and consultations. Biologists carry out the indispensable task of translating the details of an organism's function in ways that are applicable and useful to design, business, and engineering students” (Smith & Fisher, 2011, p. 320)**.**

Interdisciplinary/ transdisciplinary approach is gradually being used in design education and many experiments are being applied in biomimicry between different disciplines. With this approach, biological terminologies can be provided in common language for students. This approach helps biomimicry not to be used as a superficial process and immerges students in appropriate solutions to value the use of natural ideas in design. Therefore, interdisciplinary collaboration can certainly be of benefit for the students of interior architecture and help to develop a connection to bridge interior architecture and biomimicry.

3.4 AskNature (Taxonomy) a Tool in Biomimicry Design

Biomimicry institute has launched a website to bridge the gap between biology and other fields like architecture, industrial design, engineering, etc. This online tool enables students to access the solutions in nature, on the other hand discusses the topics and share biological knowledge through web-based collaborative learning (Biomimicry Institute, 2014).

‘AskNature’ is an online database for biological strategies and ideas to be used in natural inspiration, which are drawn from peer-reviewed journals (Deldin & Schuknecht, 2013). This website categorizes information in each page based on functioning in natural strategy.

The underlying structure of the AskNature is known by a classification system; ‘Biomimicry Taxonomy’ to organize how organisms meet different challenges (Figure 35). This tool abstracts the biological information in terms of natural functions in three classified groups (Fu, et al., 2014).

In the AskNature taxonomy, the functions are grouped in a hierarchical order in 8 groups made of 30 subgroups containing more than 160 functions. The reason of having this hierarchical order is that the strategies in nature often are associated with more than just one function.

BIOMIMICRY TAXONOMY

GROUP | SUB-GROUP | FUNCTION

- MOVE OR STAY PUT
  - ATTACH — • Permanently • Temporarily
  - MOVE — • In/On solids • In/On liquids • In gases
- MAINTAIN PHYSICAL INTEGRITY
  - PROTECT FROM BIOTIC FACTORS — • Animals • Plants • Fungi • Microbes
  - PROTECT FROM ABIOTIC FACTORS — • Excess liquids • Wind • Loss of liquids • Gases • Loss of gases • Dirt/solids • Light • Chemicals • Fire • Ice • Temperature • Nuclear radiation
  - MANAGE STRUCTURAL FORCES — • Shear • Thermal shock • Impact • Tension • Turbulence • Mechanical wear • Creep • Compression • Chemical wear
  - REGULATE PHYSIOLOGICAL PROCESSES — • Cellular processes • Homeostasis • Reproduction or growth
  - PREVENT STRUCTURAL FAILURE — • Buckling • Deformation • Fatigue (rupture) • Melting
- MAINTAIN COMMUNITY
  - COORDINATE — • Groups (self-organize) • Activities
  - COOPERATE AND COMPETE — • Within the same species • Between different species
  - PROVIDE ECOSYSTEM SERVICES — • Within a (eco)system • Between (eco)systems
- MODIFY
  - MODIFY CHEMICAL/ELECTRICAL STATE — • Regulate habitat response to disturbance • Detoxification/purification of air/water/waste • Regulate hydrological flows • Pollinate
  - MODIFY CHEMICAL/ELECTRICAL STATE — • Generate soil/renew fertility • Regulate water storage • Cycle nutrients
  - ADAPT/OPTIMIZE — • Control erosion and sediment • Regulate climate • Disperse seeds
- MAKE
  - CHEMICALLY ASSEMBLE — • Regulate atmospheric composition • Regulate atmospheric composition • Biological control of populations, pests, diseases
  - GENERATE/CONVERT ENERGY — • Maintain biodiversity
  - PHYSICALLY ASSEMBLE — • Size/shape/mass/volume • Pressure • Density • Phase
  - REPRODUCE — • Buoyancy • Light/color • Material characteristics
- PROCESS INFORMATION
  - NAVIGATE — • Number of • Speed • Position
  - SEND SIGNALS — • Energy state • Free radical reactivity • Concentration
  - PROCESS SIGNALS — • Chemical potential • Reactivity with water
  - SENSE SIGNALS/ENVIRONMENTAL CUES — • Oxidation state • Electric charge • Conductivity
  - ENCODE/DECODE — • pH • Solubility • Electron transport
  - LEARN — • Surface tension
  - COMPUTE — • Chemically generate flow of electrons
- BREAK DOWN
  - CHEMICALLY BREAK DOWN — • Adapt genotype • Adapt phenotype • Coevolve
  - PHYSICALLY BREAK DOWN — • Adapt behaviors • Optimize space/materials
- GET, STORE, OR DISTRIBUTE RESOURCES
  - CAPTURE, ABSORB, OR FILTER — • Electrical energy • Magnetic energy • Chemical energy • Mechanical energy • Thermal energy • Radiant energy (light)
  - STORE — • Polymers • Metal-based compounds • Specific stereoisomers • Inorganic compounds • Mineral crystals • Organic compounds • On demand • Attach a functional group • Detach a functional group • Catalyze chemical reactions • Molecular devices
  - DISTRIBUTE — • Structure
  - EXPEL — • Self-replicate

- Solids • Liquids • Gases
- Solids • Liquids • Gases • Energy
- Bulk solids • Gases • Chemical entities • Solid particles • Energy • Liquids
- Organisms • Solid particles • Bulk solids • Gases • Liquids • Energy • Chemical entities
- Abiotic materials • Biotic materials
- Cleave heavy metals from organic compounds • Cleave halogens from organic compounds • Other inorganic compounds • Other organic compounds • Catalyze chemical reactions • Polymers
- Balance/gravity/orientation • Sound and other vibrations • Touch and other mechanical forces • Light (visible spectrum) • Transduce/convert signals • Electricity/magnetism • Disease • Body awareness • Atmospheric conditions • Pain • Motion • Chemicals (odor, taste, etc.) • Temperature • Light (non-visible spectrum) • Electrical/magnetic • Vibratory • Sound • Through solids • Through water • Over land • Through air • Tactile • Light (visible spectrum) • Chemical (odor, taste, etc) • Differentiate signal from noise • Shape and pattern • Time and day length

Figure 35. Biomimicry Taxonomy, the underlying structure of AskNature Weblog

Depend on the nature of the design problem at hand using this taxonomy, one can find the suitable biological strategies in the nature. As an example, when someone is looking for a solution for creating energy from sunlight, he/she can refer to the group of **"Get, store, or distribute resources"**, then to the subgroup of **"Capture, absorb or filter"** and finally the function of **"Energy"** (URL 6). Under this title, he/she can find various examples in nature that can be used in this regard. Figure 36, shows steps of this process.

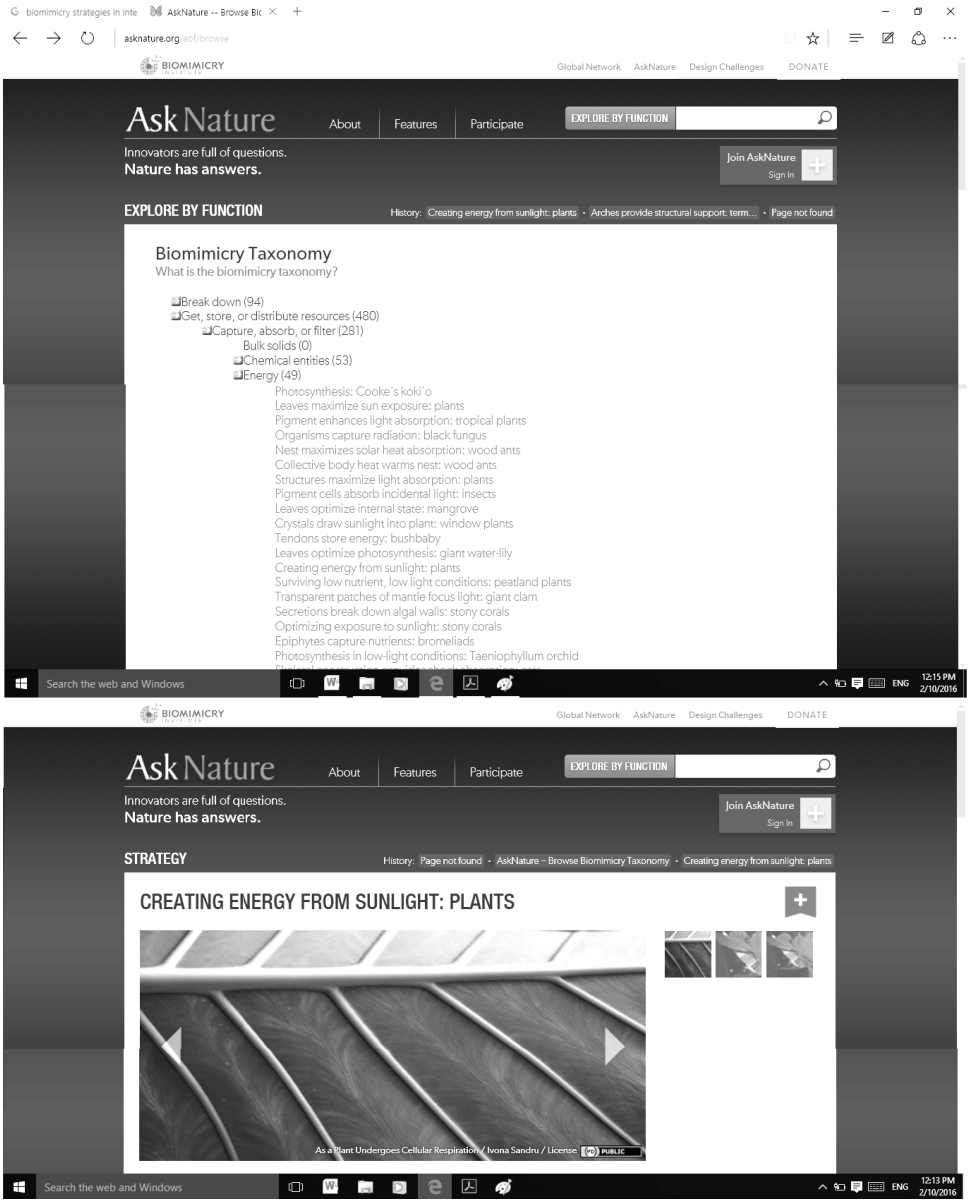


Figure 36. Two screenshot from browsing biological strategies in AskNature weblog to better understanding of biomimicry taxonomy (URL 6)

Although, many database and examples of biomimicry in design can be found at this website, but it is under development and should look forward to adapt to user's needs (Fu, et al., 2014, Deldin & Schuknecht, 2013).

3.5 Biomimicry Experiences in Design Studio Education

The design studio is the core and major component of design education. The strategy of design teaching is based on studio, which focuses on learning by doing. Studio-based pedagogy is an active learning that includes "group working" and "cooperative activities" and this is an efficient way to encourage students' learning and developing their skills in creativity, problem solving, analysis and critical thinking (Horng, et al., 2005; Jeffries, 2007; Eigbeonan, 2015; Kowaltowski, et al., 2009)

On the other hand, design studio has a suitable atmosphere to practice new teaching methods and increasing creative thoughts (Jeffries, 2007). Therefore, biomimicry experience can be an ideal option for students and studio can be a very suitable place to apply biomimicry.

One of the aims of this study is to find what has been conducted in the interior architecture studios in the field of biomimicry. Unfortunately, biomimicry practice has occasionally been conducted in interior architecture education and the published documents on experimental researches and pedagogy of this practice are very rare.

From all the existing researches on examples of using biomimicry, only five experiments which had written available documents, were in under-graduate level, and were relevant to interior architecture design. Among them, only three experiments had full descriptions and figures, and were suitable to explain in terms

of learning objectives and methodologies. Out of these three experiments, the first and second experiments can be related to interior spaces and the other is related to furniture design. As these might be beneficial samples for instructors who want to apply this method in interior architecture studios, they are described in details in this part.

Experiment 1

The first experiment was carried out in "Environmental Design" course given to Ontario College of Art and Design students by Carl Hastrich and Rui Felix aiming to "practice skills of observation" and "abstraction in nature design". This experiment is based on finding "solution" to "problem" (biology to design) approach (Hastrich, 2011).

- In the "Discover" stage that is the first phase of the project, students began with a general discussion in the studio around "Barrel Cactus". In this stage, instructors encouraged them to define the context and recognize the features of a cactus that is "adaptation to survival". Also in this part, instructors encouraged students to search about biological issues and observe everything around the barrel cactus. After that, all sketches from students' observation were collected and summarized by instructors in a table.
- Next phase is the combination of both phases of "Abstraction" and "Brainstorming" that students should practice on:

1. Biological strategies (Adapted organism, physical feature, or process).
2. Context-Habitat conditions (Can be thought of as the "challenges" that the organism has had to "solve").

3. Human opportunity (Possible human contexts where the strategy could be of value. These could include similar challenges, or new opportunities).

4. Design Opportunities (Outline of potential design opportunities, descriptions of products, process, systems or services that could be designed mimicking the biological strategy.)

- At last phase, the instructor mentioned that the last phase is always the most difficult one, relating the biological observations and insights into design. It is difficult to avoid evident, literal translations. The initial students' sketches display examples of early loose experiments that aim for broad connections. Some of the final ideas do "look" a lot like cactus, but after a while then could play with different scales of application that possibly suggest more abstract final proposals (Hastrich, 2011).

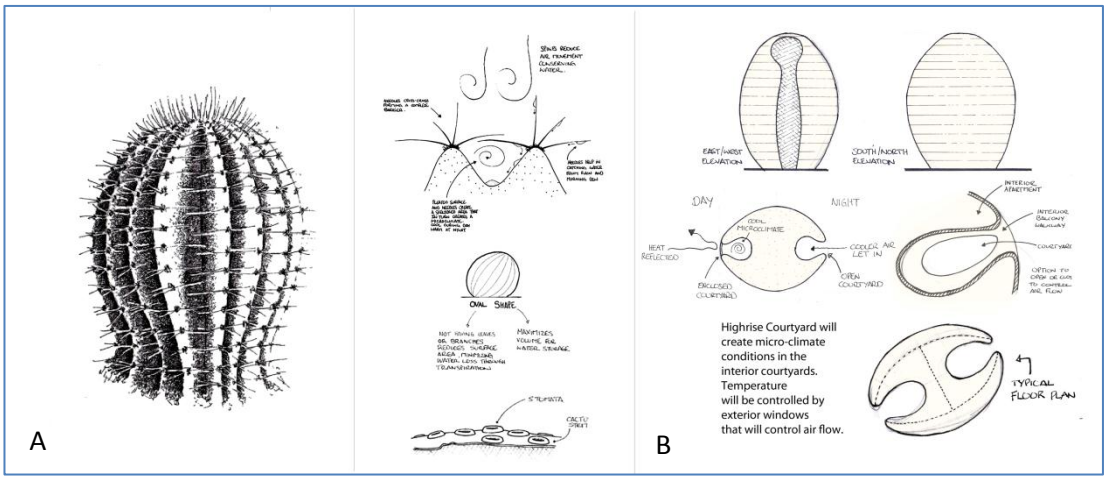


Figure 37. A. Observation Sketches of "Barrel Cactus" B. Sketches of abstracted ideas of cactus (Hastrich, 2011)

Experiment 2

The second experiment was conducted "to attain 3-dimensional thinking and problem solving skills, and be able to transfer these skills to the process of solving architectural design problems" (Yurtkuran, et al., 2013, p. 634), as a short design

problem in three consecutive weeks in the Basic Design Studio (2) course in the Department of Architecture of Uludağ University.

- In the first week, students have been divided into the groups of 4 and have been asked to do a research about "arthropods" and their physical aspects, geographical conditions within which they live, and the types of behaviors that they were engaged in, to adapt to environment.
- At the second week:

1. Each group presented research and selected photographs of arthropods in the studio and instructor provided subtle critique by asking questions.
2. After further review of research and presentation, students finalized their choice by selecting an arthropod such as Rhinoceros Beetle, Devil's Coach Horse Beetle, etc.
3. Then students were asked to conceive a scenario based on their arthropod's behavior, form, and movement for a space that would address a previously stated problem in their vicinity.
4. Groups that agreed on a specific scenario were allowed to start through sketches and working models within the studio environment.
5. During the studio exercise, the instructor inquired critiques regarding students' scenarios, the problems that they were addressing, their models, and their spatial designs.

- Final week for evaluation of the projects by instructor was based on the reasons that the specie was selected, fitting obtained solution to design and the appropriateness of the final space to the stated function, transformation of the analogy, studio activity, the group work and expressive quality of the presentation (Yurtkuran, et al., 2013).

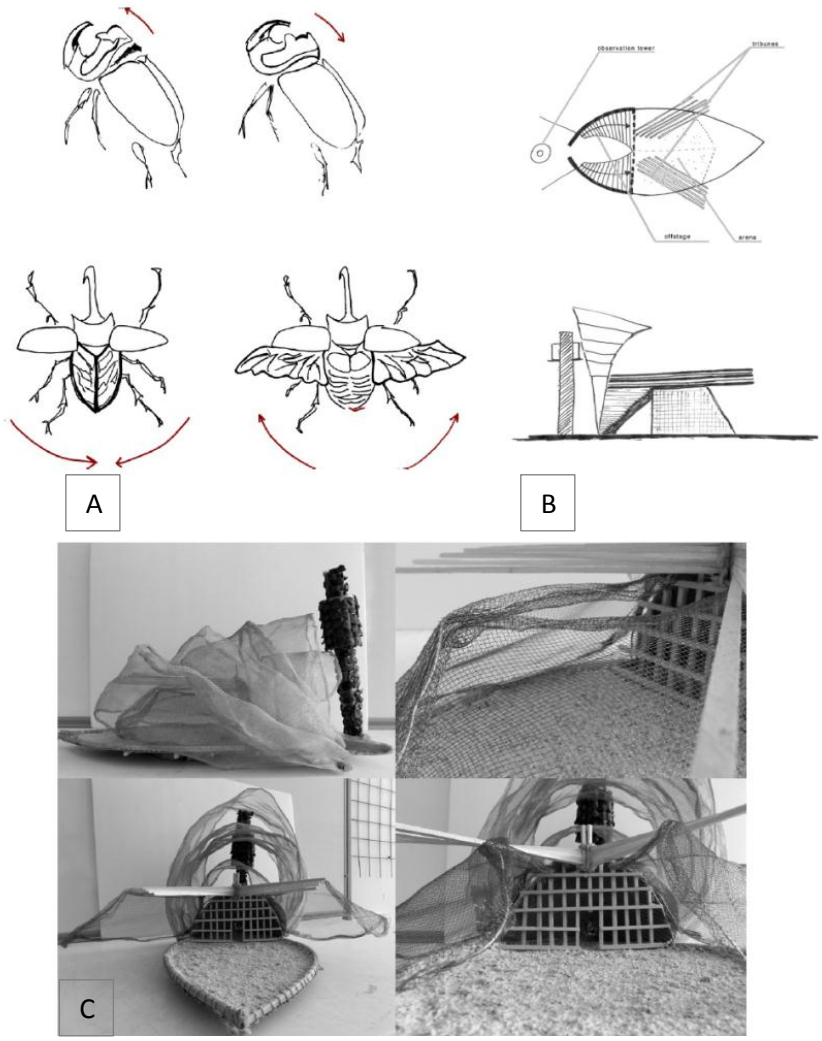


Figure 38. A. Rhinoceros Beetle and its horn and wings B. Students sketches. C. Students model (Yurtkuran, et al., 2013)

Experiment 3

This experiment was conducted on 3rd grade students in "Furniture Design" course of Department of Interior Architecture at Karadeniz Technical University, with "Aiming to create designs inspired by micro and macro sized living beings in the nature" (Tavsana & Sonmez, 2015, p. 2289). The given problem had three phases.

- The first phase began with a seminar on "Biomimicry" for students. In the second stage, students carried out a comprehensive research on the biomimicry in furniture

design. In the third stage, instructor selected white plastic stool as an available and economic product to apply formal ideas on it.

- At the second phase, the students worked on 3D models of biological forms.
- In the last phase, the best design works were applied on a 1/1 model.

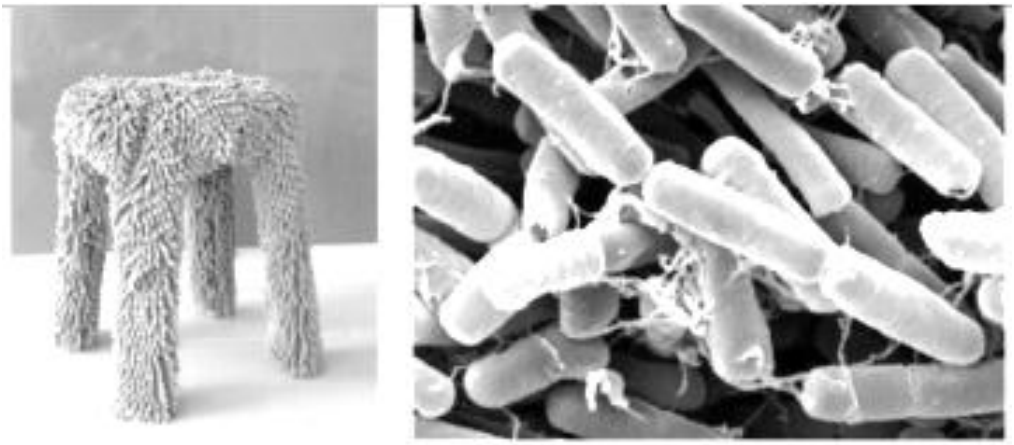


Figure 39. A student project inspired by bacteria (Tavsana & Sonmez, 2015)

3.5.1 Discussion

Although, successful examples of biomimicry applied in studio can be found in general, but the systematic approaches for using this method in design studio are difficult to find and most of them are still in experimental stage. Based on achieved results in the mentioned examples, biomimicry method can be an interesting, informative, and enjoyable experience for students (Yurtkuran, et al., 2013).

In all the mentioned experiments, the students were asked to conduct a research and discover the specific features, related on their subjects, such as features in cactuses and arthropods. At this phase, often discovering of relevant biological solutions that might be useful in their projects, can stay completely hidden from sight, because they have high complexity to find.

As result, the process of biomimicry has been limited to inspiration for forms, thus the other phases caught in a vicious cycle. Therefore, from interior architecture point of view, the emulated objects, systems, and spaces became very superficial, such as the spaces that looked like a Barrel Cactus or Rhinoceros Beetle. The discovering phase is exactly the phase that seriously needs a biologist to help and control the process.

To understand the role of biomimicry in studio, bringing other disciplines on the design table will help interior architecture students to grasp the concept better, and to prevent students from looking the idea superficially. That's why providing an interdisciplinary/ transdisciplinary studio for thinking beyond is needed.

Therefore, to enhance the integration of biomimicry into the interior architecture the case study of this thesis was chosen to examine the possibility of cooperation between interior architecture department and biology department in a university.

Chapter4

CASE STUDY

4.1 About EMU

The case study in this thesis has been carried out in the Department of Interior Architecture and Department of Biological Sciences in Eastern Mediterranean University (EMU). In this chapter, EMU and both of the departments as the context of this study, will be introduced in general, then, details about the method of study will be presented at two parts. At the first part, possibility of using biomimicry as an educational method will be investigated in the Department of Interior Architecture. Since, collaboration between biology and design is emphasized in the literature; the second part of this study will discover the possibility of collaboration between two departments.

The Eastern Mediterranean University is located in Gazimağusa, Northern Cyprus. This university offers educational programs in a wide range of the undergraduate and graduate levels, and benefits from developed infrastructures such as laboratories and a library to accommodate the needs of student society. EMU as a campus university with 11 faculties has a good chance to create an interdisciplinary atmosphere for better learning and understanding in design education (URL 1).

Figure 40. Eastern Mediterranean University (URL 4)

4.1.1 Department of Interior Architecture and Biological Sciences

The Department of Interior Architecture of EMU, tries to educate creative interior architects with developed educational programs and activities from the year 1997. This department has 14 full-time instructors and 15 part-time instructors that are working for education of more than 400 students in an English and a Turkish program. The undergraduate curriculum contains several supportive and elective courses, in addition, to design studios, which are the main core of the program and are offered in eight semesters. Two of the design studios, which are "Basic Design" and "Introductory Design Studio" in the first and second semesters, are faculty courses shared by all departments in the faculty. The students must attend 2 days per week, totally 8 hours in the design studios (URL 2).

On the other hand, Department of Biological Sciences in EMU is located in the Faculty of Art and Science. This department with 7 academic members, provides a combination of theoretical information and technical laboratory skills to educate undergraduate students. Also, this department looks forward to expand the existing programs, and develop new high-impact research clusters. Moreover, this department is assigned to develop its educational opportunities and offer some courses for non-

majors in order to provide those students with opportunities to learn and think about the larger issues in biological sciences (URL 3). Also, this department is not very far away from Department of Interior Architecture which can physically create an extra chance for a possible collaboration. Hence, university's mission and aim of both departments is to offer contemporary and updated programs to students, thus, examining new approaches and successful methods such as biomimicry can be considered to be integrated in the education.

4.2 Aim of Case Study

This study has two main parts. The first part of this study investigates the possibility of using biomimicry in the Department of Interior Architecture. The aims and objectives of this part are clarified as follows:

- To determine the level of awareness of instructors about biomimicry.
- To determine the level of application of biomimicry in the design studios.
- To discover the relation between level of awareness and application of biomimicry method in the design studio.
- To achieve the reasons behind not using biomimicry as a teaching method in the design studio by instructors.

The Aims and Objectives of the second part of this study that is done in Department of Biological Sciences are:

- To find the level of awareness about biomimicry among instructors in the Department of Biological Sciences.
- To explore the possibility of collaboration in design studios according to stuff in this department.

- To find the possible problems preventing collaboration between two departments according to the instructors.
- To find the problems in the way of using biological information by designers, instructors and students.

4.3 Method of Case Study

This case study is composed of two main parts. One part is done by making interviews and giving questionnaires to full range of instructors in Department of Interior Architecture. The second part is also done by the same process with a separate questionnaire prepared for the full-time instructors of Department of Biological Sciences. These two parts will be discussed in details in sections below.

Department of Interior Architecture

At the first phase of data collection, all of the 14 full-time instructors in interior architecture department, who are attending the design studios in different levels are chosen as sample. Additionally 2 part-time instructors that are working actively for many years in design studios are added for interview. Appointments demanded from 16 instructors and eventually 14 of them accepted to participate in interview. A combination of open-ended and numerical interview questions were designed, and then the process of interview started based on a schedule. At first, hard copies of questions were distributed to instructors and they could decide either to fill these by themselves or to interview with the author. In addition, a page with brief explanation about biomimicry and some examples was attached to the end of the questionnaire for those who might not be familiar with the topic. A sample of questionnaire can be seen in Appendix 1.

The 8 questions which were asked to the instructors of interior architectures could be grouped in 3 categories as follows:

- Personal awareness questions that are designed to explore the knowledge of instructors about nature inspired design and biomimicry as an education tool.
- Experience-based questions that are designed to explore what the instructors have done about nature inspiration design in their professional life or as a student, and the skills that they may have about using biomimicry in design studio.
- Opinion-based questions that are designed to explore what they think about the relation of sustainability and biomimicry and its usage in interior architecture. Understanding the reasons behind the observed fact, that biomimicry is not used widely in the interior architecture design studios.

Interview Results

The question 1 asked about the effect of nature-inspired design on environmental issues. Figure 41, shows that, out of 14 instructors, 12 people (86%) believed that it could positively help the environmental issues. Among them, 4 interviewee believed that these ideas can be beneficial, if nature be inspired in the right way. The right way that was mentioned in answers is to follow the natural principles and emulate its systems and cycles. In addition, one of instructors said that, bio inspired design will not be properly helpful when we stick in aesthetics of nature in design.

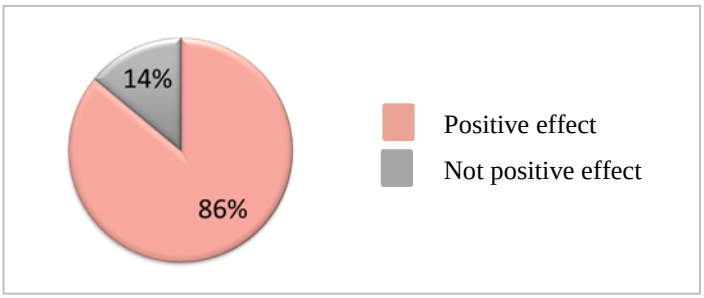


Figure 41. Belief on positive effect of nature inspiration methods on reducing negative environmental impacts

The question 2, asked about having any nature-inspired design experience in their professional life or as students. Results showed that 10 instructors had this experience, among them 6 instructors had experienced it in teaching. The instructors that had teaching experiences often had worked in the 'Basic Design' studio, and one of them had a workshop experience. Most of the experiences were about the mimicking forms and structures from nature. Besides, 4 instructors had nature-inspired experiences as students. They have been inspired by mountain, frog's egg, insects and living organisms in their design projects. One of the interesting experiences was a revitalization center and its bungalows that were inspired by living organisms.

After knowing their general opinions about nature inspiration and its effects in design, also, the personal experiences in their professional life, question 3, focused about their knowledge about biomimicry. The results showed that out of 14 instructors, 9 people (64%), were familiar with biomimicry methods (Figure 42). Among them, 2 instructors had a general knowledge about the topic, 1 instructor had a related course with graduate students, and 2 instructors had master and PhD students that were working on this subject.

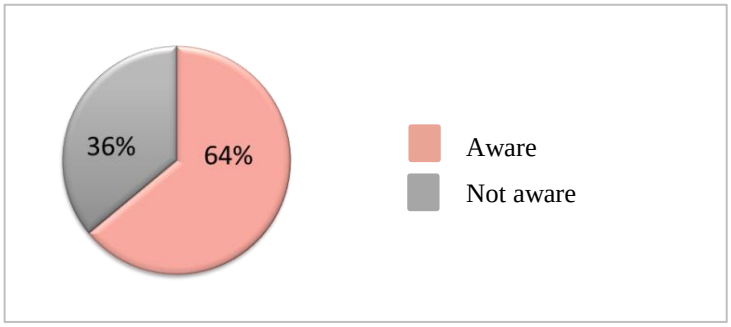


Figure 42. Awareness about biomimicry among instructors

Question 4 was about the role of biomimicry in interior architecture. Findings indicate that all of the 9 instructors (64%) that were familiar with biomimicry, believed that this method can be useful in interior architecture. Among them, 4 instructors answered that, it is a useful approach in terms of "sustainability" and can be applied on environmental control, comfort issues through smart systems, short way of doing, adaptability and less processing to be used in interior architecture design. In addition, 4 instructors said that it can be useful in getting "structural" ideas, 2 instructors said that it can be useful in "concept development", 2 instructors believed, it is useful in getting "formal" ideas in design of the elements and objects and one instructor said that it is a good way to select materials.

Question 5 asked their opinions about biomimicry information as a method of education in design studio. Figure 43 shows that, out of 14 instructors, 12 people (78%), were not familiar with biomimicry as a method of instruction.

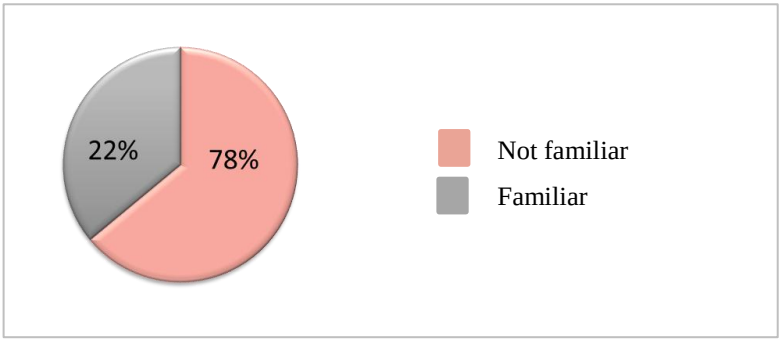


Figure 43. Instructors that are familiar with educational method of biomimicry

Question 6 asked about their experiences of using biomimicry method in studio. Out of 14 instructors, 7 of them mentioned that they had used it in their studios. They mentioned that these experiences were about concept development and abstracting the forms of organisms in studio. Out of 7 experiences, 6 were in Basic Design, and 1

was in ITAS401 (fourth year design studio). Moreover, one of the instructors had an experiment of application biomimicry in another department, Industrial Design, EMU.

In the question 7, choices were given to instructors to fill them as the reasons that biomimicry is not used widely in interior architecture studios. Instructors could choose more than one reasons. Among the reasons, 7 instructors chose "instructors' lack of knowledge", 7 instructors chose "lack of biomimicry information in interior architecture", 7 chose "lack of studio instruction to use", 6 instructors choose "lack of cooperation with biologist to access biological knowledge" and 3 of instructors chose other reasons.

The 8th and final question aimed to find the instructors' opinions about integrating biomimicry within interior architecture curriculum. Different types of answers were collected in this regard. 4 of instructors believed that to be adapted at the beginning, biomimicry can be offered as an elective course and then added to design courses' learning outcomes. 8 instructors believed that studio is a good place to teach biomimicry. Among them 3 instructors said that it can be useful if used as an approach. Instructors also pointed out to the levels that biomimicry can be applied on. Among them 3 instructors mentioned that biomimicry can be added at basic design levels. On the other hand, 2 instructors suggested that it can be used in third year of design education. One of them said, "Integrating biomimicry in design studio depends on the department and the knowledge of students. It does not matter whether you want to teach it as theoretical or formal ideas, but to use it in studio as an approach, students must have control on the principles of design at first; I guess it is suitable for our students in the third or fourth year".

In summary, findings show that, the instructors mainly believe that nature inspiration methods have positive effects on environment. Also, findings indicate that 64% of instructors are aware of biomimicry as a nature inspiration method in design. Although, this 64% of instructors emphasize on positive effects of biomimicry as a nature inspiration method and its advantages on interior architecture, 78% of them were not familiar with its educational methods in the studio (Figure 44). Therefore, it was shown that there is a 'gap' in using biomimicry as a systematic method in Department of Interior Architecture.

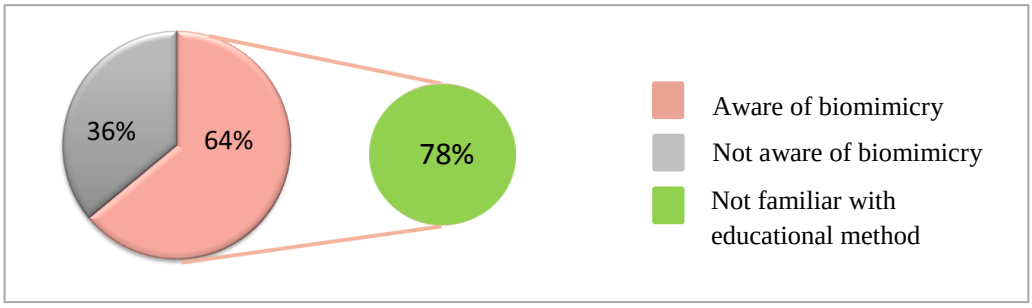


Figure 44. Level of awareness about biomimicry, and level of familiarity with its educational method

Department of Biological Sciences

The second phase of data collection was done in the Department of Biological Sciences. All of the 4 full-time instructors in this department were selected for interview. After the legal procedures, permission to do the interview was taken and after demanding appointments, eventually 3 of the instructors accepted the requests for interview. The interview contained 10 questions that could be grouped in 3 categories:

- Personal awareness questions that are designed to explore the knowledge of instructors about nature inspired design, biomimicry and its educational materials.

- An experience-based question that is designed to explore about collaborating experience in design.
- Questions about, their personal willingness to participate, and provide biological knowledge for interior architecture students.

Interview Results

Question 1, asked about the level of awareness about biomimicry between the instructors in the Department of Biological Sciences. Out of 3 instructors, 2 persons were familiar with biomimicry. One of them gave examples of the cooling system, aerodynamic structure, bio replacement and thermal comfort.

The question 2, asked about possibility of cooperation with biologists in design projects. All of the instructors in the department believed that, it is possible and it will be an effective experience for both sides. One instructor gave an example of his biologist colleagues that are working as a team in successful design projects in Germany.

Questions 3, asked about the usability of biological information for design. All of the biology instructors believed that biological information is useable for design, because most of the strategies in nature is evolved by reasons.

Question 4, asked about the understandability of biological information for designers. All of the biology instructors believed that this information should be simplified to be understandable and useful for students of design.

Question 5, asked about accessibility of the biological information with uncomplicated language for designers. All of the biology instructors mentioned that

biological information should be provided in an uncomplicated language by biologists to be used in design process. One of the interviewees mentioned about an online database; “www.nih.gov” that can be a usable source to discover biological information. One of instructors mentioned, the biological information could influence the student’s projects by categorizing the important discoveries and events in the field of biological Sciences.

Question 6, asked about their experiences in collaborative projects. As an answer to this question, all of the instructors believed that collaboration with can be used also as an approach to design education. Among them, 1 person had particular experiences with designers to exhibit biological materials, and to design a sustainable building project.

Question 7, asked about their willingness to participate in education activities in the Department of Interior Architecture. 2 of the instructors were willing to do so, but 1 instructor said it depends on being in relation with his filed of interest.

Question 8, asked about the possibility of arranging lectures or workshops by them for students of design. In this regard, all of them say it is possible. Among them, one instructor mentioned that he has already arranged a lecture, and the other one said that, arrangement of workshops is possible but for the arrangement of lectures, it needs to be discussed with interior architecture instructors.

Question 9, asked about providing courses or research material by them to be used in the interior architecture department. All of the instructors said that providing material for students is possible. Two of them mentioned that to develop course materials for

students, all instructors of both departments, who are teaching the subject, should participate in the process.

The 10th and last question asked, whether they are willing to participate in design studio as a collaborative activity or not. All of the instructors believed that participating in design studio will be an interesting experience and it is possible, but it depends on many factors such as time, because working in studio with students takes too much time and for conducting such projects, there needs to be a deliberate planning.

In summary, findings show that, although there is a large distance between these two disciplines' terminologies (interior architecture and biology), the subject was not unfamiliar to them. Out of 3 instructors 2 of them were generally aware about biomimicry concept and believed that this is a bridge between design and biology. Even it was more promising that one of the instructors had the experience on collaborative projects with architecture students before. Moreover, all of them were excited about the biomimicry concept and believed that it has much potential not only for interior architecture but also for all disciplines such as industrial design, civil engineering, mechanical engineering etc. Furthermore, they believed that participating in providing basic elements of this cooperation such as course materials and workshops in an easy language for students is possible for them. Finally, all of them had willingness to participate in a formal cooperative learning team with the condition of that this participation, matches to their subject interest and their working timetable.

4.4 Discussion

The Interviews were done and the results were collected from the instructors of Department of Interior Architecture and Department of Biological Sciences to figure out the possibility of using biomimicry as a method of natural inspiration in interior architecture. In the Department of Interior Architecture, most of the people believed that this method is a useful approach in design and can be employed in design studios to enhance the students' skills in "observation", "concept development", "abstraction" and "logic of structure". On the other hand, these instructors mentioned that using this method in interior architecture could be effective in different ways such as to create "forms", "nature aesthetic", "structural elements", "design furniture", "selecting material" and "sustainability in interior".

Given the interest in use of biomimicry among the majority of interior architecture instructors, and their experiences about biomimicry in the design studio, surprisingly majority of them were not aware of a systematic method or a pedagogical educational method in studio. Thus, this gap can be a reason that biomimicry is not being widely used in studio, and supports our findings in the literature that also points also out to this gap in design education.

On the other hand, it was obvious in the results that there is no homogeneous opinion in terms of "sustainability" as the main concept of biomimicry in interior architecture, and only 4 instructors mentioned the "sustainable effects" of biomimicry in interior architecture and most of instructors see biomimicry as an approach to apply the formalistic ideas. This can be one of the reasons that out of 7

instructors that had biomimicry experience, 6 of them worked with students on basic levels.

It can be seen from the findings that the lack of knowledge on “instructional methods” and “biological information” are the major problems regarding this gap. The second part of study explores the possibility of using biological knowledge and collaboration with biologists in design studio, as an approach to fill this gap.

Therefore, the findings from the second part of study suggest that, collaboration with Department of Biological Sciences can be a way of help to use biomimicry in design education in a right way. This collaboration may influence the application of biomimicry as a systematic and scientific approach in interior architecture studios. It seems that to establish an appropriate condition for using biomimicry in interior architecture department, first it is needed to identify the capacities of both sides to improve the gaps.

4.5 Proposal for Possible Interdisciplinary Collaboration

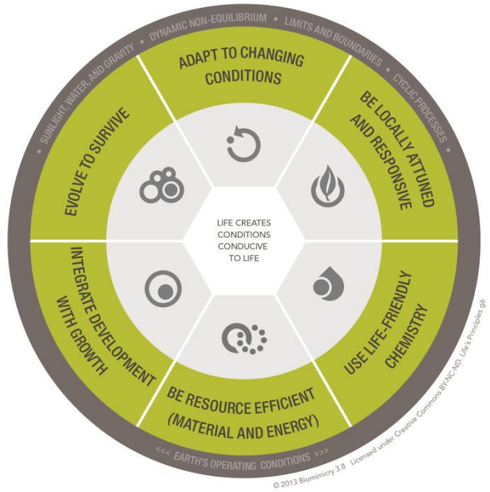
Based on the information gathered in this study, it can be said that discovering phase of biomimicry design process is the phase that, the biologist contribution can be the most. Involvement of the biologists in this phase of design makes it possible for the designers to reach to and to understand the natural strategies. In the education process too, although collaboration with the biologists can help in all stages of the process but it is profound in the discovering stage. Actually, in the ‘biology to design’ approach the presence of the biologist from the very beginning of the process is necessary but in the problem based model (Challenge to Biology), which is the model that is used mostly in the design studios, biologist contribution in discovery

phase as a transdisciplinary approach can help in discovering natural models and abstracting biological strategies. Figure 45 demonstrates the stage that biologist's contribution is necessary in the design studio with a different color.

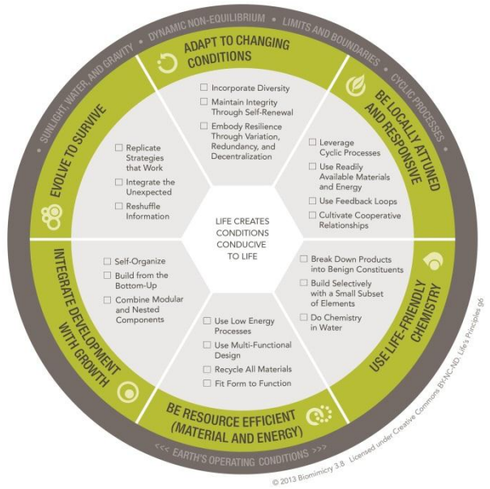
1. Define Context

2. Identify Function

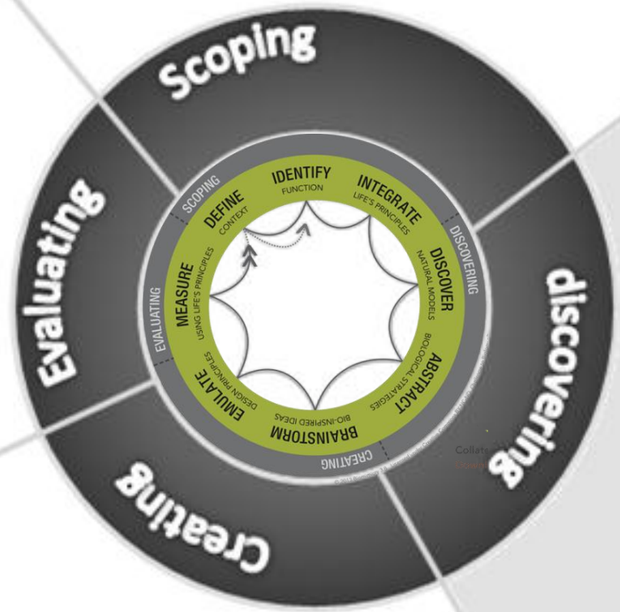
3. Integrate Life Principles



8. Measure Using Life Principles



7. Emulate Design Principles

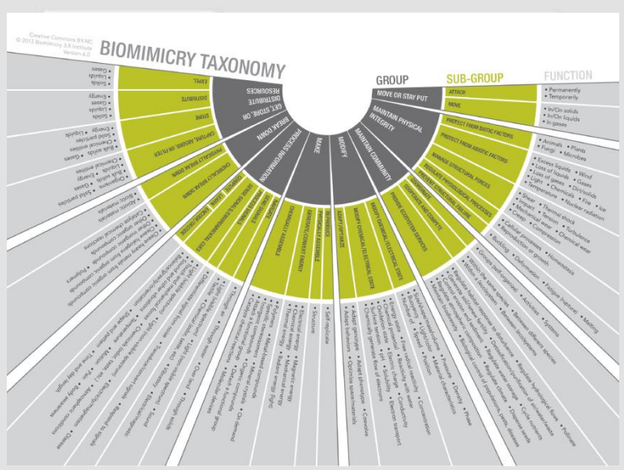


6. Brainstorm Bio Inspired Ideas

4. Discover Natural Models

Interdisciplinary approach

AskNature Weblog



5. Abstract Biological Strategies

Figure 45. The discovering phase of biomimicry, as a possible part for integrating biologist in design studio

Chapter5

CONCLUSION

This study expressed this fact that biomimicry is not a new concept, but is a new discipline. Many of basic ideas of today's life have been driven from nature many years ago. Nature's time-tested strategies in a single organism, behaviors or systems can be an exciting prospect for future of human design (Benyus, 1997).

On the other hand, interior architecture design in recent years is ready to accept these ideas because, the problems in the built environment are increasing and future of human habitats should be revised with a sustainable pattern. In this regard, biomimicry as a sustainable process can be of paramount importance for next generation designers especially students in architecture and interior architecture, through expanding the effective methods and applying biological solutions in design process.

In spite of popularity of biomimicry and various educational programs now carried on in many universities, institute and research centers around the world, this method has not been much used in interior architecture studios. Therefore, to investigate this problem, Department of Interior Architecture in Faculty of Architecture in EMU was selected as a case study.

According to the results obtained from the case study, it has been revealed that majority of instructors in the Department of Interior architecture are not familiar with an educational and systematic method to be used in design education. The results also showed that while all of the instructors believed that biomimicry as a useful approach can be used in interior architecture, only 28% mentioned sustainability as the main concept of biomimicry in interior architecture and majority mentioned the other aspects related to inspiration from nature in interior architecture.

While searching appropriate methods for using this approach in interior architecture between few founded experiments that were published, unfortunately no strong method that has potential to be used widely in design studio was found . On the other hand, the learning objectives in founded examples often were focused on enhancing skills such as thinking, brainstorming, observation, creativity in basic levels, rather than using a “problem solving method in terms of sustainability”.

Since, none of the founded experiments introduces a sufficient systematic method in studio; the research methodology tried to figure out what reasons are influential in creation of this gap. In the related literature, three difficulties found as the main obstacles in using biomimicry approach in design process. These are: “difficulty in transferring analogy”, “lack of knowledge” and “identifying relevant solutions in biology”. These inherent complexities not only exist in biomimicry but also they exist in all other nature inspirational methods. These complexities were similar to the difficulties that instructors mentioned in the interviews. Some of them mentioned that in their experiences the link between research part and design concept could not be built up.

Pioneers of biomimicry method, identified these difficulties and tried to overcome the mentioned problems by collaboration with biologists in the design process. Although several tools and frameworks were introduced by experts in the body of this process to facilitate deployment of this method, but interdisciplinary collaboration with experts from other disciplines such as biology certainly can be the best solution to fill this gap.

In recent decades, many universities have benefited from collaborating with other professions in design studios in various fields. Eastern Mediterranean University as a campus university has a good chance to benefit from biologists in design education, and Interior Architecture Department can be a pioneer in initiating biomimicry teaching with a systematic educational method.

To investigate about possibility of collaboration, to understand the potential of Biological Sciences Department, and the possible problems in the way of this collaboration from experts in biology's point of view interview with instructors in this department was added to the methodology. The results indicate that, the subject of biomimicry is very interesting for them too. In addition, most of the instructors had willingness to collaborate in interior architecture design studios. Still, a strong determination between the two departments needs to pave the way for the realization of this aim.

Finally, successful examples in biomimicry in interior architecture demonstrate that the concept of sustainability continues to grow in this field. Developing technology and the vast range of available strategies will be able to affect positively in increasing the sustainable quality in interior architecture. As a result, this idea is not

true that biomimicry in interior architecture can only be a source of inspiration for forms and structural elements. These examples show that this approach can be effective in enhancing indoor quality in various ways such as providing day lighting, thermal comfort, energy efficiency, durability, and productivity. All these issues play a significant role in future of building design. Hence, it is essential to teach and should be included in design education in interior architecture by relying on systematic educational methods that are interactive in an interdisciplinary way. Therefore, this topic is open to explore for future studies because if we want to spread it and apply it in design studio, we need to have more feasible tools, clear processes and invitation of biology knowledge on design table.

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APPENDICES

Appendix A: Questions for Department of Interior Architecture

Eastern Mediterranean University
Faculty of Architecture – Department of Interior Architecture

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This survey is being conducted as a part of a master thesis study to assess "Usage of nature inspired methods (Biomimicry) in design studio." This survey is entirely voluntary and your identity will remain anonymous. Any feedback you provide will be kept confidential and only summarized results will be included in the written report of the thesis.

We hope you will give all of the questions your full consideration. The survey should take no more than 20-30 minutes to complete. Please answer each question to the best of your ability.

Thank you in advance,
Seyedmohammad Taghavi
Graduate Student (Eastern Mediterranean University)
Faculty of Architecture, Department of Interior Architecture

Questions:

1. Do you believe that nature- inspired designs can reduce the negative environmental impacts in the world?

2. Have you ever had experience of using nature as a source of inspiration in your designs (as a professional or as a student)? If yes please explain.

3. Do you have any information related to Biomimicry or bio-inspired design methods?

4. Do you think inspiration by nature in design (Biomimicry) can be useful in interior architecture? In which way?

5. Do you have any information about Biomimicry as a method of education in design studio?

6. Have you ever used Biomimicry as a method of teaching in your own design studio? If yes, please explain how and in which class. If not please explain why.

7. What do you think are the reasons that Biomimicry is not used widely in interior design studios? (you may mark more than one)

☐ ……Instructors' Lack of knowledge about Biomimicry

☐ ……General lack of information on Biomimicry in Interior Architecture (examples/ researches)

☐ ……Lack of instruction on how to use it in the design studio

☐ ……Lack of cooperation with the biologysts or accessing potential solutions in biological research

☐ Other (pleaese explain)

8. Do you believe that Biomimicry should be thought as an approach in interior Architecture within the curriculum? Do you believe that this can help in increasing the usage of this method in interior design field?

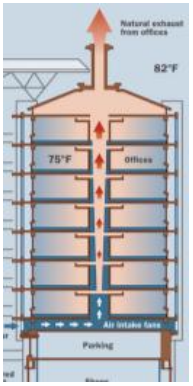
Biomimicry (from bios, meaning life, and mimesis, meaning to imitate) is a new discipline that studies nature's best ideas and then imitates these designs and processes to solve human problems.

Examples:

Studying a leaf to invent more efficient solar cell (Structure)

Inspiration from pattern of jungle floor to design interface carpet. (Form and colour)

Inspiration from termite mounds to have efficient air circulation system and use less energy.



Appendix B: Questions for Department of Biological Sciences

Eastern Mediterranean University
Faculty of Architecture – Department of Interior Architecture

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This survey is being conducted as a part of a master thesis study to assess "Usage of nature inspired method (Biomimicry) in design studio." This survey is entirely voluntary and your identity will remain anonymous. Any feedback you provide will be kept confidential and only summarized result will be included in the written report of the thesis.

We hope you will give all of the questions your full consideration. The survey should take no more than 10-15 minutes to complete. Please answer each question to the best of your ability.

Thank you in advance,
Seyedmohammad Taghavi
Graduate Student
Department of Interior Architecture, Faculty of Architecture
Eastern Mediterranean University

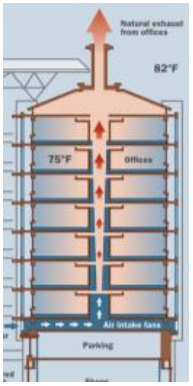
Biomimicry (from bios, meaning life, and mimesis, meaning to imitate) is a new discipline that studies nature's best ideas and then imitates these designs and processes to solve human problems.

Examples:

Studying a leaf to invent more efficient solar cell (Structure)

Inspiration from pattern of jungle floor to design interface carpet. (Form and colour)

Inspiration from termite mounds to have efficient air circulation system and use less energy.



Questionnaire:

1. Had you heard about biomimicry? Do you have any information on nature-inspired designs?

2. Do you believe that it is possible for designers and biologists to collaborate in design projects?

3. Do you think that it is possible for designers to use the information provided by biologists in the design process?

4. Do you think that it is easy for designers to understand the information provided by biologists (due the terminology used in your field, etc.)?

5. Do you think it is possible to make biological information accessible with uncomplicated language for students of design?

6. Have you ever had any experience of collaborating in some design projects? If yes how?

7. If asked, are you willing to participate in design education activities in interior architecture department?

8. If asked is it possible for you to arrange lectures or workshops for design students on your research subject?

9. Can you provide research materials, etc. for the students of design if they ask it (if biomimicry method is used in a design studio)?

10. If asked, are you willing in participating regularly in a design studio which uses biomimicry method?