Nature as a Source of Inspiration of Architectural Conceptual Design

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Submitted to the
Institute of Graduate Studies and Research
in partial fulfillment of the requirements for the Degree of

Master of Science
in
Architecture

Eastern Mediterranean University
October 2009
Gazimağusa, North Cyprus

ABSTRACT

From the beginning of creation, human being was surrounded by nature. Everything in nature is well organized and in harmony with the other parts of it. Through the history, nature has been always a source of inspiration for the human begin in different aspects of their life. Architecture as one of the remarkable features in every society cannot be separated from nature.

In this thesis, the role of nature in architecture has been discussed in order to find out how architecture has been affected by nature throughout the history. Based on the aim of this study, the thesis concluded that nature has the most optimized organization in terms of form, function, structure, and material within the context.

In architecture design works even the ones which have been designed so close to nature, still there are some missing parts in one of their forms, function, or structure. Therefore, the best solution for the architects and designers to increase the optimization in their design works is looking at the nature in every aspect deeper and try to apply them as much as they can in their conceptual design of their project which is the heart of the design process, the point at which the actual form, character, and design details of the project are the best established and finalized.

Although, there are a wider areas of inspiration from nature studies in architecture like organic architecture, constructive architecture, deconstructive architecture, and etc but this study is not going through the philosophy of inspiration from nature and it focusing on the more engineering ones like bionic architecture, Biomimicry and levels of inspiration.

This study has intended to draw the attention of architects as well as architectural students to nature and inspiration from nature in different perspectives.

ÖZET

Yaratılışın başından beri, insan, doğa tarafından çevrilmiştir. Doğada herşey en iyi şekide organize olmakta ve diğer bölümleriylede uyum içindedir. Tarihte doğa,insanin yaşamında herzaman hayatının farklı açılardan başlamasında ilham kaynağı olmuştur.Bu bağlamda her toplumda mimarlık doğadan ayrılamayan dıkkat çekici özelliklerden biri olmuştu.

Bu tezde, mimarinin tarih boyunca doğa tarafından nasıl etkilendiğini bulmak amacı ile doğanın mimalıktaki rolü tartışılmıştır.Bu çalışmanın amacına dayanarak, tezde, doğa; form, işlev, yapı ve malzeme bakımından en etkili organizasyon olarak akdedilmiştir.

Mimari tasarımda, doğaya en yakın tasarımlarda bile form, işlev, yapı bakımından hala bazı eksik tarafları vardır. Bu nedenle, mimar ve tasarımcılar için en iyi çözüm, kendi tasarımlarında doğa ile etkileşimi atımak için; her açıdan doğaya daha derin bakmalı, tasarım sürecinin kalbini oluşturan projenin kavramsal tasarım kısmının gerçek formunda, karakterinde ve detaylarında yapabildiği kadar uyğulamayı denemeli, en iyi ilişkiyi kurmalı ve sonuçlandırmalı.

Bu çalışmada, farklı yaklaşımlarda doğadan ilham alarak mimarinin yeni bir dönem için, farklı prespektiflerden bakılarak, yeni yaklaşımlar göstermek amaçlanmıştır.

AKNOWLEDGMENT

I would initially like to express my sincere gratitude to my supervisor Assist. Prof. Dr. Munther Mohd for his vast knowledge and invaluable feedback. This thesis would not have been completed without his support and trust in me.

I am also thankful to all my friends; amongst them, my special thanks go to Halleh N.riyahi, Kamyar Arab, Sarvenaz Baradarani, Oznem Sahali for being with me, supporting me and encouraging me through all stages of my study. I should also say my deep thanks to my lovely wife Maryam who has been always my great support throughout my study and she has never left me alone.

At last but not least, the deepest thanks go to my family; my parents, for the support they provide me throughout my life. Without their understanding and help this thesis would remain only a dream.

Thank you all…

……..TO MY FAMILY

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CHAPTER 1

INTRODUCTION

1.1 Overview

Once earth created and all creatures were started to live on it; most of the creatures naturally start to create shelters for themselves like the birds, rabbits, and etc. human being as one of the creatures on the earth, start to makes hut and shelters to be protect from climatic conditions and their enemies. Humans also like other creatures from the old ages tried to look after themselves from the climatic conditions like rain, wind, snow and etc and other possible dangers .To be able to survive they start to make shelters for themselves by available natural materials and by referring to some natural structures like the bird's nest and other animal huts. They were not considered on the aesthetic aspect of their shelters form as much as structure and stability.

By the time passing development of technology gives more opportunity for humans to have more variety in design of their shelters. These improvements can be seen easily by looking back to history of architecture. Early humans used to dwelling in the caves; which was ready in nature and mostly for winter shelter, but in summer days they chooses to be outside for the hunting and gathering as shown in Figure 1.1. Living outside for the hunting and gathering, purpose the need of temporary shelters. At the earliest level, it means the beginning of architecture.

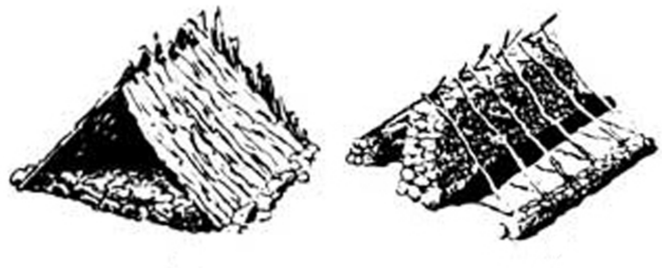


Figure 1.1: pre-history shelters structure and design

Later on when humans started agriculture business instead of hunting, permanent settlements become a factor of that time (8000 BC). The story of architecture is beginning by evolving the tent-like structure into round houses as shown in figure 1.2 and figure 1.3. The technology of bricks, which is shaped by the mud and baked in the sun, is invented in that age of architecture. Later on the shelters are developed to the buildings by the straight walls with windows (6500 BC).

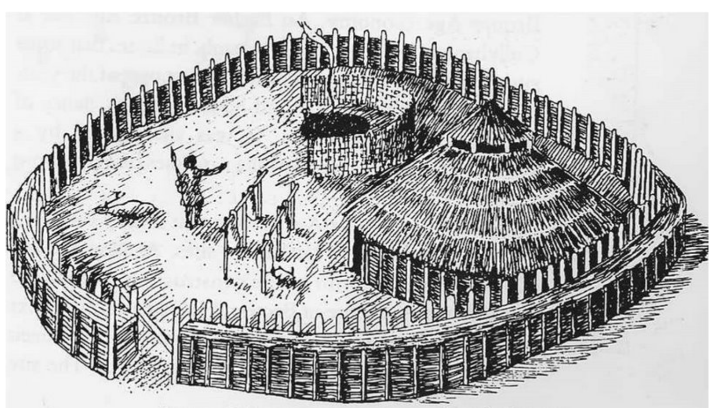


Figure 1.2: Round houses

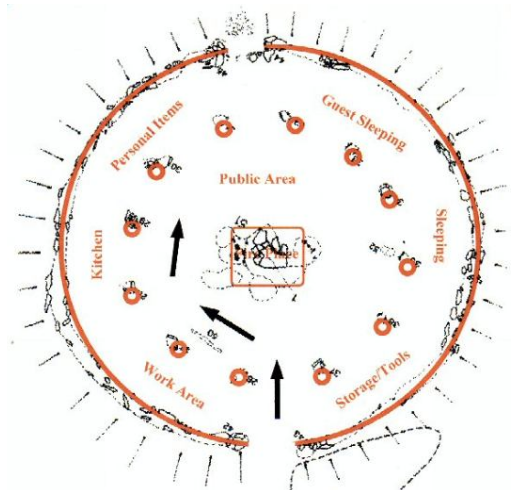


Figure 1.3: Round houses typical plan

After that the Stone Age is came; buildings are constructed from the block of limestone and later on the creation of arches, domes, vaults and etc. These improvements are continued up to the one of the biggest enlargements which was the industrial revolution and in side of it coming up the Iron Age, architecture is also overturned in these age, structural systems and architectural forms turned to be more complicated as it comes to today's and going toward tomorrow.

As these technology growing faster and faster each day, some scientist feels that the nature can be the best source for humans to learn from it. They believe that organism did all the things that humans want to do but without demolish their environment and future.

Architecture is a creative activity; it creates a completely new building on a site anywhere there was an empty piece of land and building design is flexible. Architecture provides in different solution under unique situation and the early stages differ in character rather from the later ones, mostly because of the greater fluidity of the condition. The early stage, when there are still major decisions to be made, is referred as the called conceptual design stage. A good conceptual design requires an inventive mind, an excellent grasp and understanding of the main parameters which have to be optimized in order to achieve the best result whilst conceiving a structure. The best results are obtained when the structure fulfils its function with a good relation of the other design details like material, form, and the context. There is less consideration of inspiration from nature in most projects in the early stage of design, for this reason the designer should be familiar with the relationship between the conceptual design of any project and the nature. Based on conceptual design decision and principles of inspiration from nature the best project can be considered as that project which will have inspiration in different aspect of nature.

Janine Benyus base the new science in 1998 under the name of Biomimicry. Biomimicry means "innovation and inspiration from nature looking to nature as a teacher". She says that:

"in the 3.8 billion years since, life has learned to do some amazing things to fly, circumnavigate the globe, live at the top of mountains and the bottom of the ocean, lasso solar energy, light up the night, and make miracle materials like skin, horns, hair, and brains. In fact, organisms have done everything we humans do or want to do, but without guzzling fossil fuels, polluting the planet, or mortgaging their future."

By Biomimicry she got 12 main ideas from nature like self-assembly, solar transformation, the power of the shape, etc. There will be a question here what if we as an architect as a small part of this society could learn from nature, to optimize our design from the economy, material, function, structure, form points of view within the context; as nature done, it solves the problems in the context which is the same context as we have our problem in it which is the earth.

Many architect are in believe now that nature can be a powerful and trustful sources as frank Lloyd wrought said:

"Study nature, love nature, stays close to nature. It will never fail you."

Or in the other words describing power of nature by Louis Kahn is:

It is my feeling that living things and non-living things are dichotomous….But I feel

That if all living plants and creatures were to disappear, the sun would still shine and the rain still falls. We need Nature, but Nature does not need us.

In the discussion of architectural theory, and in the curricula of school of architecture, one finds little concern for inspiration from nature especially in the early stage of design and the central focus of this study is the link between conceptual designs and nature because there are many interconnection between conceptual design and nature. This research intends to identify the sources of inspiration and the levels of inspiration of nature for architectural conceptual design.

Although there are many fields of philosophy in the case of inspiration from nature like organic architecture, but this research is not going through them and its going to focuses on more mathematical and engineering point of inspirations like bionics, Biomimicry and etc.

1.2 Aims and Objectives of the Study

From the history of architecture is clear that architecture is started by getting help from nature to use it directly or getting idea from it but as the technology is developed its affect on humans life and also architecture and day by day architecture is getting far away from the nature, but also fortunately as it's getting away from nature the architects and engineers are feeling that by forgetting the nature their products are guzzling the nature and without nature we cannot be also; so they try to get back to nature and find their solutions in nature.

As the natural architecture has a form, function, structure, material, in a optimize way; this study is going to find out a way to optimize the architecture by learning from nature; it is going figure out how nature is optimized in design and how it is possible to use the same method in architecture to optimize the architectural creations and getting inspiration from nature. How we should look to nature as if it is our teacher.

The author believes that this study is exactly what is needed to help the architectural students to get inspiration from nature for the conceptual design. Consequently, this research will show architectural students and architects the level of inspiration and the sources of nature for their conceptual design.

1.3 Research Methodology

This study is a part of huge area that sought determines how get inspiration from nature and how nature can affect on conceptual design decisions and factors in any projects. The methodology of this research is includes the literature survey and documentary research and case study, rather than developing a new approach that sought respondents' general opinion about inspiration from nature. As a case study some examples of inspired building design will be analyzed considering the levels of consideration and the sources of inspiration.

1.4 Thesis Outline

This study is structured so that each chapter is largely free-standing and this will allow to reader to make easy reference to the material. The order of the chapters begins by considering the natural inspiration and its relationship with conceptual design.

The rest of this thesis is organized as follow:

Chapter II contains literature survey. This chapter gives a clear definition of inspiration from nature and how it effects on the other fields where nature is significant. Some of these books and some papers are related to inspiration from natures that have been published in the last 11 years which are summarized in this chapter.

Chapter III reviewed the history of architecture. This chapter examines the development of man-made architecture. The purpose of this chapter is to demonstrate the architectural form development from the pre history time to today architecture from where it comes and where it is going.

Chapter IV focused on the design and architectural samples in nature. This chapter is explaining some natural samples and the design strategy and structural details of them and compares them with man-made ones.

Chapter V contains some structural samples in nature. This chapter describes the structural systems which are used in nature and their relation with the man-made structures.

Chapter VI focused upon the architect and inspiration from nature. This chapter highlights the level of inspiration and also the sources of inspiration by analyzing some case studies.

Chapter VII provides the conclusion and future directions.

CHAPTER 2

LITERATURE SURVEY

It is of some interest to briefly review the historical evolution of the various architectural design concepts and structural engineering and especially the inspired ones from nature.

Most of the science are start to looking back to the nature and inspire from it and many research and studies are done through this idea as it mentioned in previous chapter this idea start from 1998 by Janine Benyus seriously. Now a day's many researchers are working on it because they feel that nature is a great source to get inspiration from it.

Architecture and bionic is an international workshops which is born in 1993; it has different ideas to learn from nature in architecture industry. One of the main ideas of this international workshop is to learn the techniques which nature is using to creating. Their work is based on idea which is says: "the alternative to confront future is to learn the lesson that nature offers us to get more with minimum effort." The design in nature is in the optimal way in all direction like material, function, form and etc; this can be a helpful lesson for architects and designers. "The proposal of bionic science is simply a return, once again, to nature, with the objective to encourage and attitude of coexistence with the total realty of the universe. We could resume saying 'learning from nature, building future.'" (Pioz, 2000)

Jirapong believes that nature has many great lessons for human to study and learn from it. The creativity use of material, resourcefulness structural systems act in response to dissimilar kind of climatic and environmental forces make natural forms as a preeminent model form for man-made architecture. (Jirapong, 2002)

Tomasz and Rafal in their Structural design inspired by nature are saying complicated design problems needs novel solution to solve and as most of the solution already done in nature we can get inspire from nature bay three different levels which are:

1. Visual inspiration
2. Conceptual inspiration
3. Computational inspiration

And also it defines three different source of inspiration from nature which are named as Evolution, Co evolution and Morphogenesis; each of these sources have different section; for example Evolution has individuals, fitness, selection, inheritance. Finally it shows that nature can be a dominant source of inspiration, and we got "new era of nature understanding and ability to computationally simulate nature's processes."(Tomasz A., 2005)

Richard Bonser in his Biomimetics buildings looking to find out that: "What nature can teach us to improve sustainability?" there is question here which is "why copy nature?" and to get some answer for it maybe we can have look on what Leonardo Da Vinci said about nature: "the genius of man may make various inventions, encompassing with various instruments one and the same end; but it will never discover a more beautiful, a more economical, or a more direct one than nature's, since in her inventions nothing is wanting and nothing is superfluous."

Finally he believed that learning from nature (Biomimetic) is important because it may give more sustainable solutions to human's problems. (2005)

Vaculenco provides that in many years nature has worked out and updated itself, and creating forms and systems we may find out by today technology as an example in figure 2.1 and figure 2.2. For architect maybe the most interest parts of nature is the forms and the shapes which are existed in nature, for analysis these forms it's better to know how they created and according to Maxim V. Forms in nature appear by one of the below process:

- Uncontrolled process.
- Process that depend on the laws of physics and chemistry of nature and of their formation environment.
- Processes guided genetically and by the condition of environment.
- Processes guided by human demands.

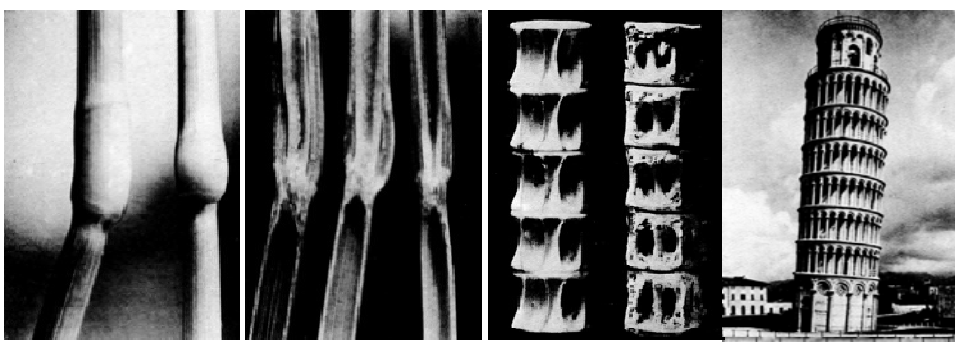


Figure 2.1: "Constructive systems of column type"

Another key sentence of him is "the shapes of objects surrounding us are connected to a general factor the environment where they take place"; for the first step from the architects' point of view to take inspiration from nature it can be a good point. Next idea is that "there is no shape without function in nature, as well as function without shape. Harmony between function and shape in material world is one of the most important tasks of the nowadays designer." Getting idea from nature (Bionic) has five main categories which are:

1. Total mimicry.
2. Partial mimicry.
3. Non-biological analogy.
4. Abstraction.
5. Inspiration.

As result of this maybe we can say that in nature forms functions and the surrounding environment for each element are in direct relation that can be good lessens for architects. (Vaculenco, 2005)

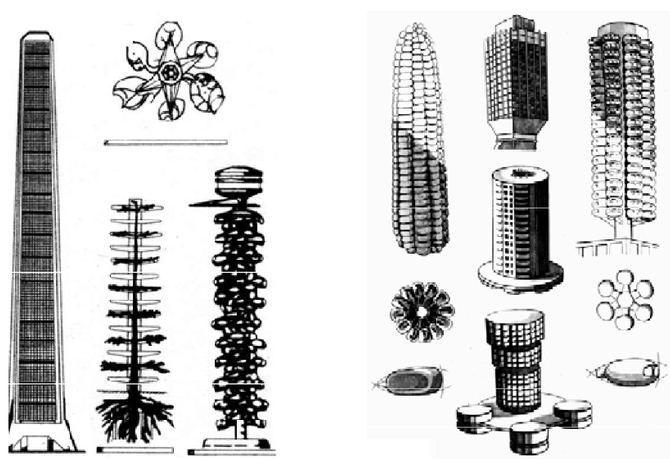


Figure 2.2: "Bionic structure in forming of architectural constrictions"

Sha sha has focused on variation in modern Bridge design becoming more difficult, bridges are getting more similar because of some standard diagrams, but as a designer they are caring about the aesthetic point. For this reason some designer are trying to use bionic as a method in the bridge design. Bionic architecture defined as two types; the architecture that imitate the appearances and function of living creature, and architecture that imitate a structure's appearance, structure and function. By the help of nature now they found some new material and structural system in a bridge design and it helps innovation in bridge designs. (Sha Sha, 2005)

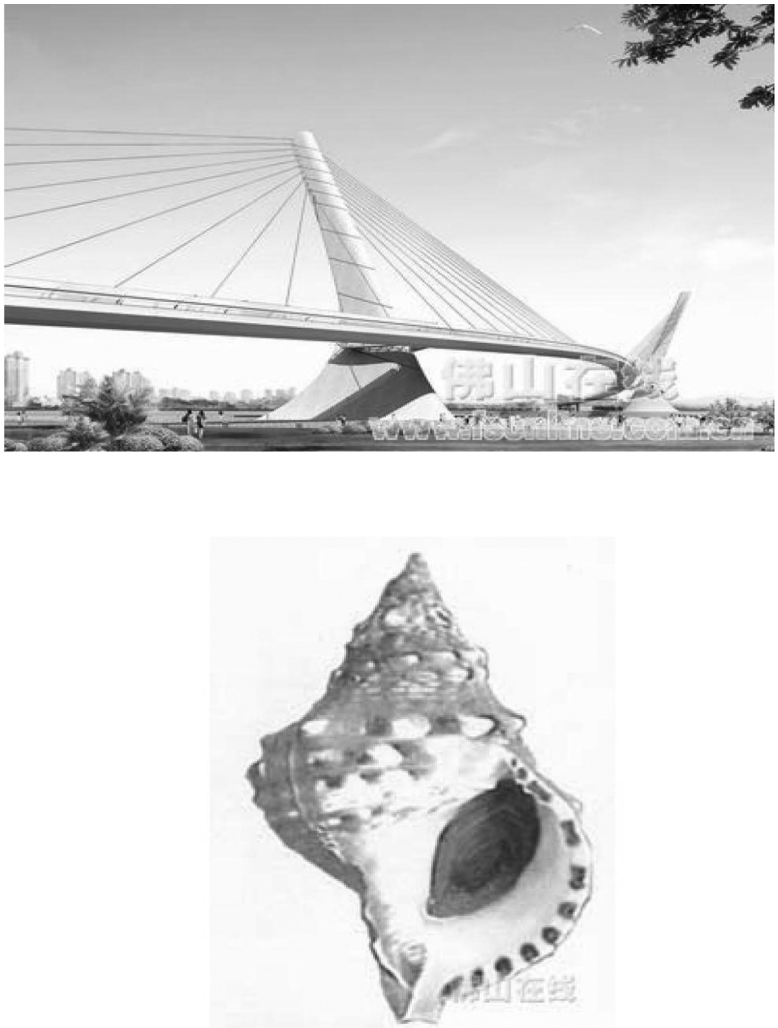


Figure2.3: “Theme and archetype of the footbridge design in Foshan city”

There is another specialty under the name of bionic. It is a science which makes a linkage between biology to technology. It appeared in 1960 in United State for the first time. The idea behind it is that, nature was a great source of inspiration for human begins to create tools or indicate himself as an artist. “Bionic is an interdisciplinary filed on the way to establish itself a science. Bionic deals with mans use of structure, methods and processes found in biological systems in relation to technical development." Why bionic should merge with architect and designer education. One of the reasons of this is "Bionic fits our focus on methods in integrated design including interdisciplinary team work." (Stokholm, 2007, P, 7-13)

Dragomirescu examine that Bionic as a key field to make connection between biology and the world of engineering is getting more and more interest from many different industry; also needs of it in education appears as some university are opening some course in this field like Politechnica university of Bucharest in one of their conferences mentioned about this subject under the name of bionics in engineering. As Neumann defined bionic as, "Bionic is the scientific discipline, which is in charge with the systematic transfer of construction, process and evolution principles of living systems into technical applications." And Natchigall in other words say, "Bionic is learning from nature for creation of independent technical solution." So maybe we can say that it is somehow necessary for engineers and other industry to have information about biology and bionic to find out their answers from nature. (Dragomirescu, 2007)

Figure 2.4: “Lotus-effect at work in nature, (paint, Self cleaning, Food container, self cleaning roof)”

The concept of biologic architecture invented by Dan Winter; such a kind of architecture is “a set of rules that determine which symmetry or quality of electric field allows all biologic structures to thrive. The premise behind biological architecture is that all life responds well to design that is in accordance with nature and avoids harmful materials and sharp corners which bleed capacitive charge.” In the other paragraph he mentioned the goal of biological architecture and he says: “the ultimate goal of biological architecture (Figure 2.5) is to create fractal charge fields that are implosive in nature and encourage life.” And they had done some research on the effect of biological architecture on human life on the large scale like city planning and etc.

Figure 2.5: “Artificial accumulator”

Figure 2.6: “Biological capacitor”

In above example they analysis and found out in the biological capacitor the life is germinate 33% more than artificial one. (Ponce de Leon, 2007. P1-2)

Kurk explore that is there any reason to look to nature for design, Billions of year’s nature had done the optimal way to produce and cerate. “Nature solution are not only optimal in design, they are also always based upon life-sustaining principles.” The main idea to visualize nature as a teacher is: “to build effective design solution that are also compatible with life.” In the other word it says: “inspiration from our natural world to optimize and distinguish our design” (Kurk. F, 2008)

On the side of these studies of inspiration; in architecture architect and designer had some ideas and philosophies of inspiration from nature like organic architecture and many architects was worked in this area like Louis Sullivan, Frank Lloyd Wright, Antoni Gaudi, Rudolf Steiner. The main idea of the organic architecture is "inspiration from the principles of living nature. This often led to free and expressive forms. These where not meant as an imitation of nature, but to support people as living and creative beings". (www.organic-architecture.org. 2009)

This survey shows that inspiration from nature is far from a well-defined area of study in architecture, and that it would either eliminate some of the concerns refer to or else turn out as broad and general as to be little practice value. It should be understood that this attempt is limited to particular perspective that of the architects who tries to get better grasp of the inspiration from nature for architectural design decision and tries to understand how these inspiration affect others involved in architectural projects.

CHAPTER 3

EVOLUTION OF MAN-MADE ARCHITECTURE

3.1 Introduction

This chapter aims to bring in the historical development of the architecture forms which are created by human. In this section, the early and new forms of the structural systems are discussed under the name of the pre-history and the modern architecture. To achieve this, the related structural elements and its complete forms are examined with the art of the forms and the architectonics components of the structural systems are discussed under the stability of the forms for the different architectural forms. In this chapter the structural requirements which are covered equilibrium, stability, strength, functionality, economy and aesthetics are discussed with the relation of the natural forms with in their context, and at the end of this chapter the human made architectural forms tabulated which are used in later chapters to find out the new modeling for optimizing of the architectural design products.

3.2 Beginning of Man-made Architecture.

Architecture started from the time that human being feels that they need to go out of the caves in summer times for hunting and gathering; they start to create the primary shelters to protect themselves from the climatic conditions and other possible dangerous. To start architecture the only available source that they could use it or getting idea from it was nature. They create their shelter by getting idea from the bird's nests and other animal hut as it shown in figure 3.1; and create their first natural tent by using the trees branches and leaves. The first human dwelling trace found from as early as thirty thousand years ago.

Figure 3.1: Inspirations from nature in pre-history

Later on in the same period of architectural history they shift the tent system up as a roof structure system of round houses and improved from the tents to the round houses (8000 BC) by the new technology of bricks made from mud and dried under the sun, this improvement started from the time that humans start the agricultural business by the side of hunting. Cities start do grow by the settlement of human begin and the houses is shaped the straight walls and windows; as the history shows "One of the best preserved Neolithic towns is Catal Huyuk (Figure 3.2), covering some 32 acres in southern Turkey. Here the houses are rectangular, with windows but no doors. They adjoin each other, like cells in a honeycomb, and the entrance to each is through the roof."

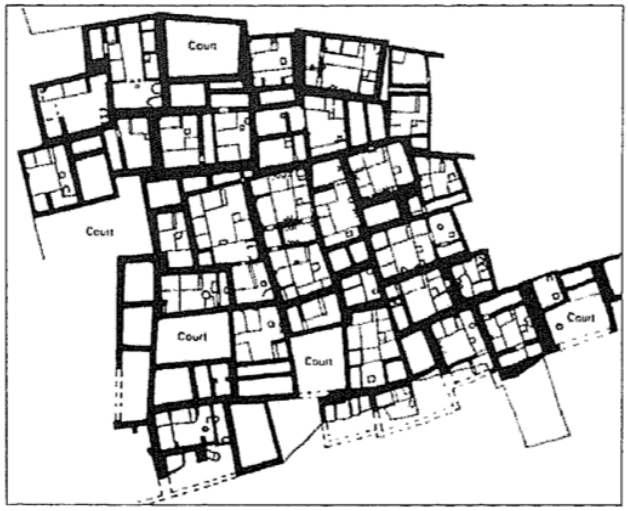


Figure 3.2: Catal Huyuk city plan

After the bones and trees branches implement the early improvement of human tools was the stone material and later on it went to be the building material. Stone Age made a challenge in narrative of architecture by the invitation of stone tools and instrument and via these tools they start to grave the stone pieces to construct the buildings and mostly the temples. One of the fist and historical stone monument is Stonehenge in England as it shown in Figure 3.3; which was the genius of architecture on that time.

Figure 3.3: Stonehenge in England

3.3 Early Civilization and Acceptable Architecture

Civilization defines as a culture with a relatively high degree of elaboration and technical development. The term civilization also designates that complex of cultural elements that first appeared in human history between 8,000 and 6,000 years ago. Somehow we can say civilization is started from the time that human start to use the bones, stone and surrounding available material to make a tools and structural elements. But the civilization in architecture is started from the ancient Egypt and pyramids (Figure 3.4) which were great sample of this civilization in that time.

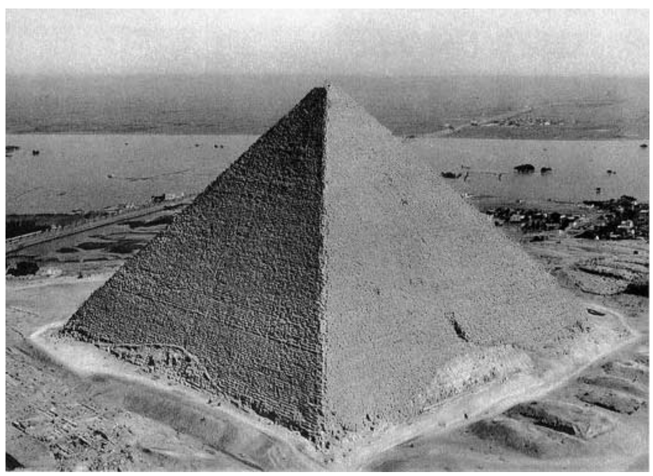


Figure 3.4: Pyramids in Egypt

In short after the stone age and invitation of new tools by stone human start to invent more new material and tools like bronze, iron, steel and etc. by the invention of these materials new tools in invented and in help to architect to create more detail in their building and these development was not too much in structural systems it was effect more on the interior and exterior decoration detail; but the most important change is happened after the industrial revolution at the late 18^{th} century and early 19^{th} century.

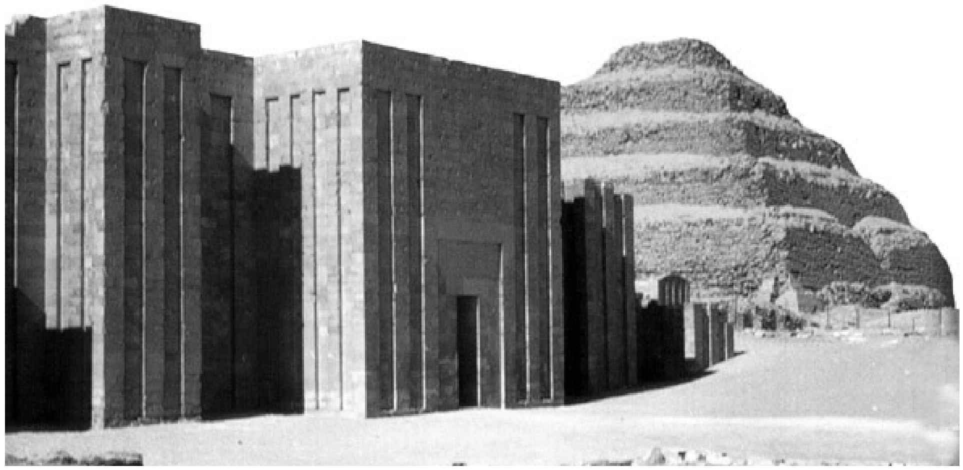


Figure 3.5: Pyramid of Djoser and parts of its surrounding wall.

Although humans invent new tools and material but still the material that he used was directly from nature and just the design ideas are altered in compare with pre-history periods. As it mentioned in that time humans for creating their shelters they were getting idea from nature like bird nest. After civilization and invention of new tools their architectural forms is change but still they had some idea from nature. Development in technology is getting faster and faster and it effect all the industries especially architecture which by looking through the history and the building forms it is easy to feel it.

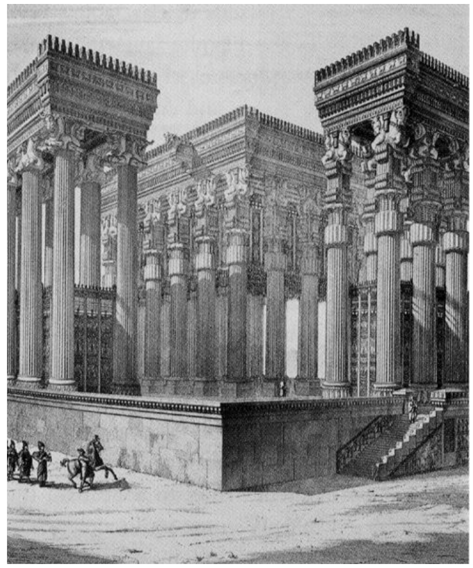


Figure 3.6: Persepolis complex in Iran, 6^{th} BC

For example by looking to Persepolis complex which is one of the architectural monuments, the different of it by the primer shelters is understandable the forms, scale, planning and structural systems are completely in contrast.

Figure 3.7: The Parthenon temple in 5^{th} BC

For a period these development of technology and architecture also was in the slow timeline. Suddenly by industrial revolution the great change happened in all industries and also it effects on architecture. In this period the invention of machine and also mass production helps to create more and fast. The forms, shapes and design idea are also change totally for example the Eiffel monument (Figure 3.8) which is in different style of its previous ages.

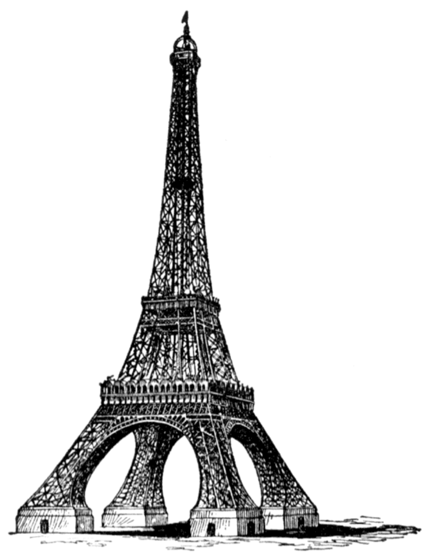


Figure 3.8: Eiffel tower, one of the first steel structures

The land value is in that periods also affect in architecture and gives idea to architects and designer to start constructing more than one level, the multi storey building is invented as it shown in figure 3.10; in that time which was a new point in architecture from the functional and formal point of architects.

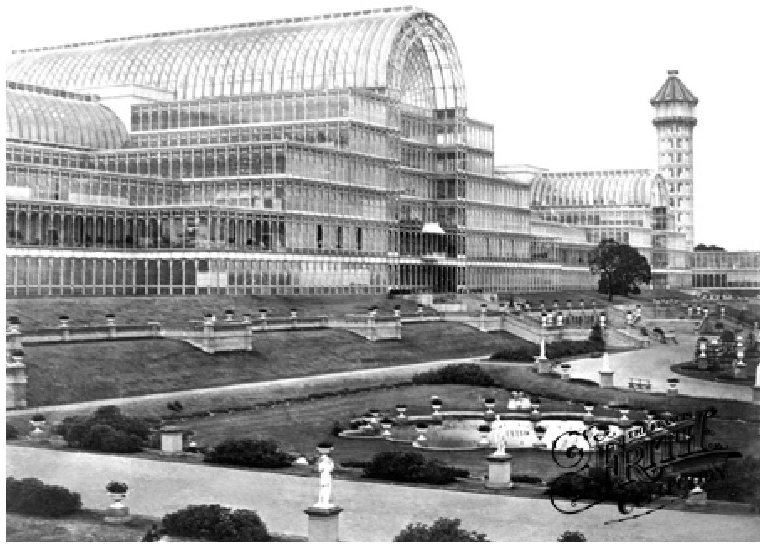


Figure 3.9: Great exhibition hall, steel monument

Figure 3.10: Multi-storey building

3.4 Modern Architecture

Modern architecture style is started in 1940s as international style. The different idea in this style from the previous ones that we discussed is the way the architect are looking to function. “Function” is not only practical in this period it is including all criteria of use enjoyment, perception and aesthetic of the building. In 20^{th} century another consideration is added to decision of architects by the side of above consideration the sustainability is became a principle for designers and architects. (Arab K.2007)

“Through its aesthetic dimension architecture goes beyond the functional aspects of that it has in common with other human sciences.” These theories and ideas helps to creation of many new lines and styles in architecture. One of the examples of these new changes in that time is Bauhaus school (Figure 3.11), founded in Germany in 1919 which is rejected the history and direct architecture as a synthesis of art, craft and technology. (Arab K.2007)

Figure 3.11: Bauhaus school

Modern architecture was the pioneer of its own time for architects and designers until the First World War, which architect tried to provide the social and economical order of post-war. The building forms are reduced to pure forms and architects removed the historical references. Architects like Mis van der Rohe created the building by exposing the structural systems like steel beams and concrete surfaces instead of hiding them behind the historical forms as shown in figure 3.12; and his creation is based on the inbred qualities of building material and construction technique.

Figure 3.12: Farnsworth House done by Mis van der Rohe at Plano, Illinois 1946-1950

In the same time some architects was not agree with modernism, because they believed that it's devoid of decorative and ornamented style. Postmodernism is developed as a reaction of modernism architects like "Robert Venturi's contention that a "decorated shed" (an ordinary building which is functionally designed inside and embellished on the outside as it shown in figure 3.13) was better than a "duck" (a building in which the whole form and its function are tied together) gives an idea of this approach." (Arab K.2007)


Figure 3.13: Gordon Wu Hall done by Robert Venturi at Princeton, New Jersey in 1983.

The development of architecture and technology was getting faster and faster as the years are became closer to today. As we studied in pervious parts humans was limited with the tools and available material in pre-history and they were inspiring from nature because of these limitation but new technologies were giving more opportunity to architects and designers to create free with less limitation and because of this the design idea and concept are not getting inspiration from nature and building forms and structure are became more free, these facilities are motive to create a competition between architects and designers in their design forms and styles. The ideas are architect were getting away from each other for example I. M. Pei does not believe that architecture must find forms to express the times or that it should remain isolated from commercial forces.

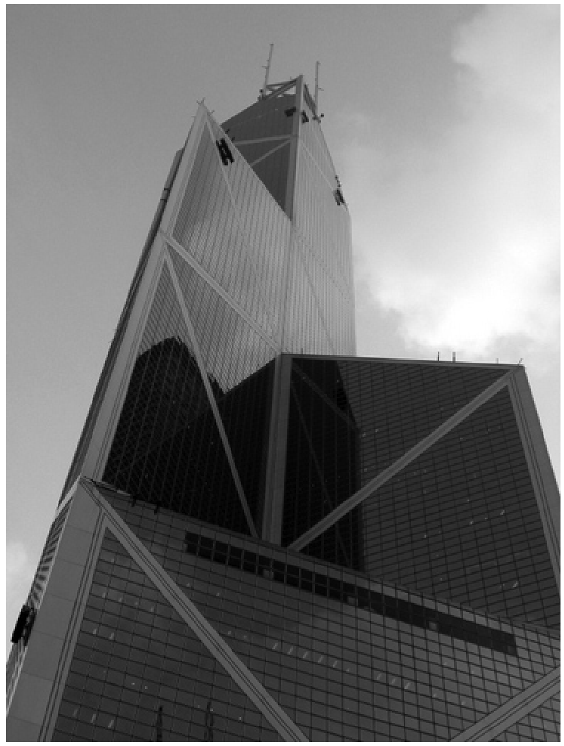


Figure 3.14: Bank of china done by I. M. Pei at Hong Kong 1982-1990

The aesthetic point of architecture was become more important for some architects and they made it exaggerated in their designs as much as that the building is show up like a sculpture. As an example of these architects we can mention the name of Frank Gehry which he creates a sculptural building in one of his famous design which is Guggenheim museum (Figure 3.15). In this position many new architectural styles showed up like deconstruction and many new free forms are started to build up in these ages. (www.greatbuilding.com, 2009)

Figure 3.15: Guggenheim museum done by Frank Gehry at Bilbao, Spain, 1997

Many other architects are start to work in the free form styles and the building shape and forms are become as a fashion so because of this the material that are used is became more artificial instead of natural ones unlike the traditional architecture. These facilities let the architect and designer to create whatever they want in any where they like, they don't have any limitation of place that they want to work, because they can have any material in any place that they want by the technology of todays. Can we say it is better to have such utilities or not should be discussed in the later chapters? In the same years some architects like Zaha Hadid had done somehow the same style as Frank Gehry by some differences.

The other difference which is showed up by the help of technology is the scale of the building which are somehow became out of human scale a large building and high towers.

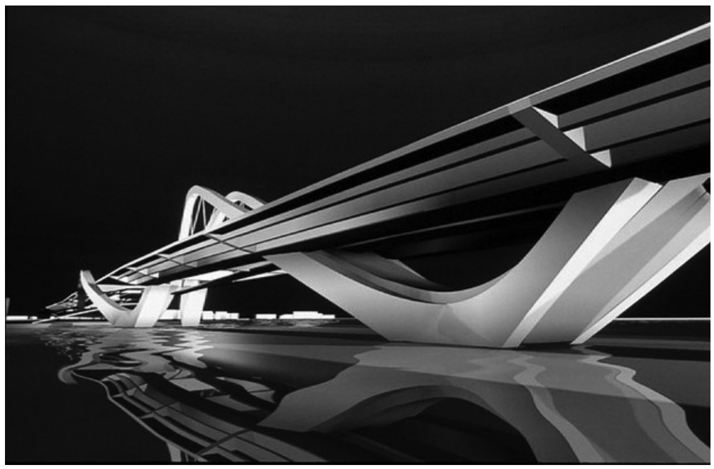


Figure 3.16: Rosenthal Center done by Zaha Hadid in Cincinnati

3.5 Future Architecture

The designs of the buildings are getting more complex day by day and some future example of architecture is showing this complexity in their architectural forms. This complexity leads the architecture away from nature.

As an example of this futuristic architecture we can mention to Death star Lunar hotel (Figure 3.17) which is done by Cate Trotter in Baku, Azerbaijan. "Hotel Crescent is designed as a counterpoint to Hotel Full Moon, with its column supports being disguised by its arched façade. The two hotels will be joined by three tall residential buildings and a fourth 43 floor office building standing 203 meters tall. If Full Moon Bay can just shake off the 'Death Star' vibe, it's looking to be an amazing development."

Figure 3.17: Death Star Lunar hotel done by Cate Trotter in Baku, Azerbaijan

Many ideas are created for the future of architecture in a very huge difference with the modern and today’s architecture which can be seen in the examples like below which is done by Stazek Marek as it shown in figure 3.18, which is maybe going to be a complex.

Figure 3.18: Complex at the center of universe, done by Staszek Marek

Another conceptual example is a building in the middle of waterfall which is named water plant created by David Gonzalet in Spain.

Figure 3.19: Water plant created by David Gonzalet

Figure 3.20: Mega Village done by Andrew Barton

The above example is a conceptual design idea for a mega village in 2108 this is created by Andrew Barton.

As another example of futuristic architectural design we can mention the towers in Dubai which are done by Thompson Ventulett Stainback shown in figure 3.21 and Associates. “This building design not only futuristic, but also evolutionary and innovative achievement, Located in Dubai, UAE the four towers, ranging from 54 to 97 floors, are clustered to form a choreographed sculpture, representing the movement of candlelight.”

Figure 3.21: Candlelight Towers done by Thompson Ventulett Stainback and associates in Dubai

In all of these proposals of architectural building for future we can see that the buildings are exaggerated from different points of architectural element like structure, function, forms and etc. and it seems that they are going to away from nature totally from the architectural points of view these buildings are very interesting and exciting but from the ecological and from our surrounding natural points of view maybe they will not be a good ideas and designs. This can be answered by the analysis of natural architecture in the later chapters and compare it with these proposals.

3.6 Summery

By attention to the evolution of architecture through the different periods, a considerable point comes up to be discussed. As it has been shown in the early period of architecture the only source for the human being to take an idea was nature; but by the appearance of technological developments, abilities of human being in order to create new products increased.

Gradually, their respect to the nature decreased and sometimes they completely forgot about nature. The following chapters mostly focused on architecture in nature and different aspects of that.

CHAPTER 4

ARCHITECTURE IN NATURE

4.1 Introduction

This chapter aims to introduce the historical evolution of the various specification and systems related to the natural architecture and design. Therefore, considering the biological systems, the homology between natural and the man-made architectural forms and design are examined, and the historical evolution of the various natural (living) systems and forms are discussed in order to modeling the natural structural systems which are used in later chapters to find out the advantage of natural structure which is optimization and try to come up with a way to have the same method in man-made architectural design.

4.2 Nature and Design Systems

Engineering methods and theory have led to considerable progress in biology, and the study of structures, forms, organs, systems, and processes in living nature, properly applied, has assisted the engineers, designers and the architects in finding broader and improved solutions for their problems.

It is simple to understand that the homology between natural and man-made architectural forms can be seen while considering the biological systems and structures. According to the definition of "structure", the meaning of this word can be expressed as "the arrangement or formation of the tissues, organs, or other parts of an organism" Therefore, since nature has unlimited time and resources, due to its natural selection uses methods of infinite subtlety for its chemistry and control mechanism and therefore its progress in evolution was depending upon the development of stronger biological materials and more ingenious living system.

In turning to more detailed discussions of the natural structure, it is clear that the natural structures can be categorized under three different main groups.

(a) Homo-Sapiens: According to structural principles of homo-sapiens are counted as the perfect example one can find in nature. Humans have different kind of structural systems which all work in an integrated way. These structural systems can be classified as follows:

i) Blood circulation system,

ii) Nervous system,

iii) Skeletal system

iv) Digestive system

v) Respiratory system.

In this chapter considering the blood system of the homo-sapiens the new discussion were generated in order to understand the analogy between natural and manmade design groups (Under, and Mohd 2007).

(b) World of the Plants: Considering the structural principle of the plant forms it is easily seen that their shapes, materials and structural characteristics change with the climate and region. Therefore, these intrinsic worth of the plant forms inspire new interest in living nature in order to understanding of the science and the knowledge of the behavior of materials and the structures.

According to Fisher, 1964 fine-membrane structure in nature (Victoria regia) leaf skeleton of the tropical water lily (Figure 4.1) were modeled for London Crystal Palace, and this was the turning point in architecture (1850) which gave the new direction for the entire development of architecture.

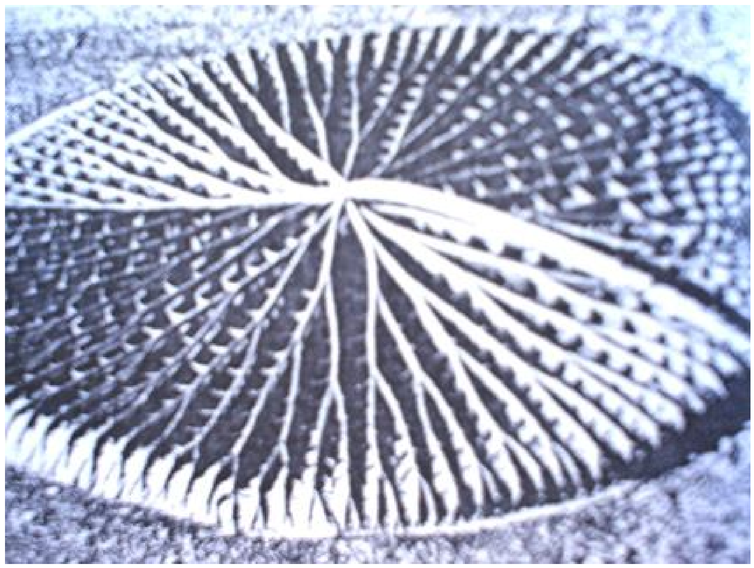


Figure 4.1 Fine-member structure in nature: Victoria regain leaf model for the Crystal Place

(c) World of the Animals: Considering the structural principles of the animal world of the living forms, the analogy between architecture and biology can be found under disciplines such as structural science. After publishing the book of "zoomorphic" of the animal forms which is related to the new animal architectural forms, this new trend evidence of architecture can be considered as new turn to nature.

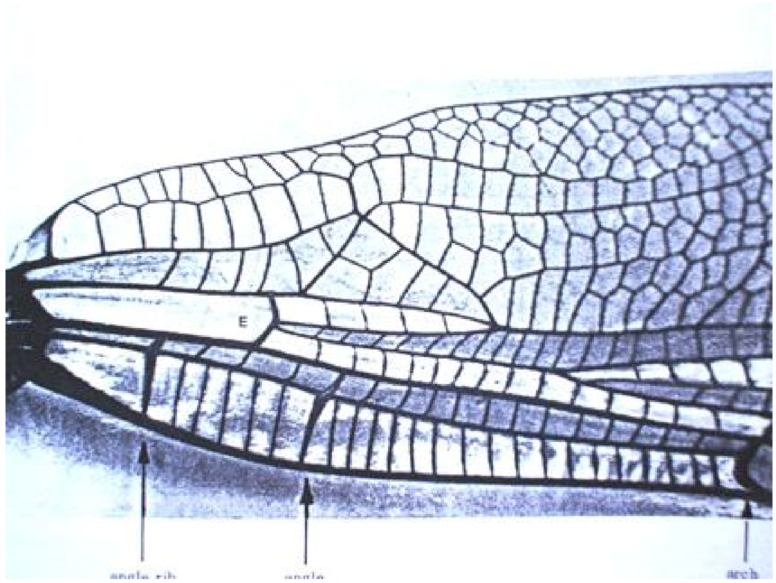


Figure 4.2: Dragonfly (Aeschna cyanea), Wing close to the body, Pleated structure

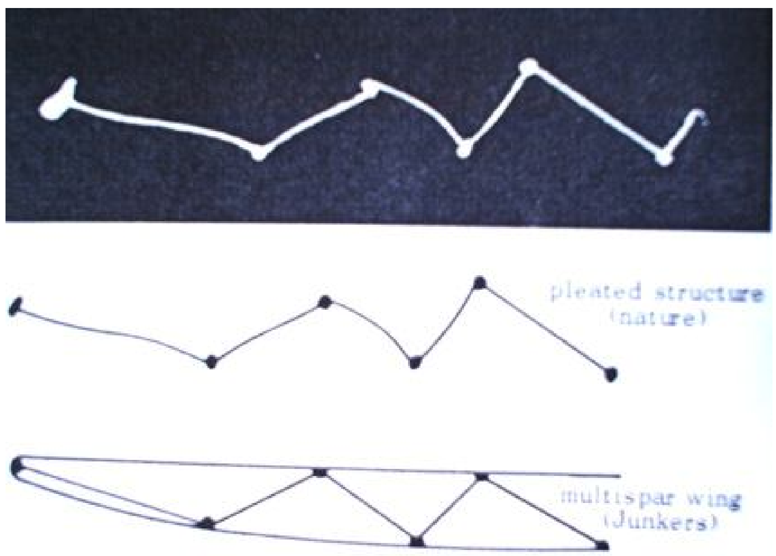


Figure 4.3: Dragonfly (Aeschna cyanea), plated structure and wing profile

4.3 The Invention of Nature and the Strategy for Design

Through history, the biological systems can be considered as a very well developed branch for architects, designers and engineers. Therefore, even a very simple and primitive kind of life can be considered as a delicately balanced. However, for the development of the natural forms the selection of the nature can be considered as an accepted model for the latest designers and this explanation called according to the Darwin as “natural selection”. (Gordon, 1978)

Among these great explanations, the design for function and invention, which can be considered as grandest form of design in both engineering and nature, it draws out general principles of evolution.

According to French 1994, the crucial inventions of nature can be considered as their development in the fossil record. The organization of living material in a cell with a cell wall and a nucleus, the transmission of the blueprint of its design and its means of self-construction and the very important device of sexual reproduction, all developed in minute organisms which have left little evidence.

Additionally, another important invention of chlorophyll can be seen in all green plants and enables them to convert the energy of sunlight into chemical energy belongs to the same early stages in the development of life.

Another big step forward was the development from single-celled organisms of multi-celled ones. In this discussion it is not clear that why single-celled organisms could not have continued to increase in complexity and size. The reason of this can be considered as the fundamental limitations of the way the genetic code works. This idea can be considered in such a way that it is more convenient in engineering and architectural activities when a system is sufficiently complex, to divide it into modules or sections, and it can be considered as an equivalent effect in nature.

Among these great inventions, another important invention can be seen development in animals of tough outer casings which served the purposes of both skeleton and armour. This invention, on which are based insects of all kinds and crustaceans, like shrimps, crabs and lobsters is very economical of vital material and weight and has provided immensely successful, however it has one crucial limitation which apparently nature has been unable to overcome. These casings, or exoskeletons, cannot grow with their owners, and must be moulted with each increase in size.

Another important invention can be considered as, the internal skeleton, typified by the backbone, the distinguishing feature of the great call of animals, including the fish , the amphibians, the reptiles, the birds and the mammals which can be considered as vertebrates. Considering the earliest fishes, the first important group included backbones, were heavily armored, but their supporting systems was an internal skeleton. Therefore, the function of protection and the structural support were separated, and this proved to be a great advance. Among all these invention, later most fishes last their armor, because it was more of an encumbrance than a protection.

Besides all these, an important invention nature made in the fish was its covering of scales, the remains of its armor and the scale demonstrates an important characteristic of design in nature, which is that generally every new thing must develop from some old thing. Thus, the scale was transmogrified into one of the inventions of nature which is most pleasing and admirable to the human designers, that elegant, subtle and astonishing structure.

Another important invention was the ability to keep the body temperature constant. Therefore it can be considered that the great dinosaurs had developed this power and this can be showed that, another tendency in design, both living and human.

Considering the remarkable invention in plant design after chlorophyll, the sexual reproduction of the insects can be one of the important inventions in order to use of special adopted flowers to enlist the services of animals. Therefore, flowers can be considered as the sexual organs of the higher land plans, and many of them rely on wind to carry the male pollen to the female stigma.

As can be observed from various description about the some important invention of the nature, since nature has unlimited time and resources in order to understand the development and the infinite variety of the biological systems for living organisms, the related observation were studied under the Institute for Light weight Structures (IL) at the Technological University of Stuttgart, Germany under the direction of Frei Otto.

According to Hertel, 1964 since nature has unlimited time and resources, it is not therefore, surprising that nature has developed systems and components which are incomparably more advanced and superior to all that homo-sapiens. Therefore, considering this explanation such blindness warps us in many ways:

(i) In the life of mind, thinking is clouded by false concepts.

(ii) In science, theory is overemphasized, and therefore the triumph of the "exact" formula and the computer were seen.

(iii) In practical life, we find neglect and disregard of the greatest of master teacher: living nature.

Therefore, according to our chemists, physicist, engineers, and designers the nature can be considered as an interested enough in the wonder of living nature to establish a biological-engineering approach for our problems. These new architectural bones, skins, brains, and muscles combine to become a new organic engineering, to make buildings that have the adaptive strength of living systems.

Figure 4.4: Natural Structures

According to the Institute for Light weight Structures (IL) at the Technological University of Stuttgart, Germany under the direction of Frei Otto, 1973 so many important extensive researches were studied in order to in order to understand the development and the infinite variety of the biological systems for living organisms. Therefore, briefly outlined, the program points of IL for years 1973-1976 can be considered as:

(i) Architectonic and constructive principles for object-oriented research.

(ii) Archives, documentation and terminology in the area of light and wide-span surface structures.

(iii) Ascertainment of a comparative ratio of dimensions for constructive application for various structures and structural components

(iv) Division of forms and constructions in living nature and technology as a basis for design and form determination.

(v) Position of technology and history of design in lightweight construction.

(vi) Form determination methods, measuring technique, evaluation and presentation of lightweight construction design. Judgment of form and design behavior in mutual dependency.

(vii) Evaluation of experience on completed structures in relation to utilization, bearing behavior, material, etc.

Therefore the preparation of these IL works and IL results were related to determining the attitudes of biology and architecture as disciplines. The observation that first there were biological systems, and then architecture as a complementary system. Thus, architecture and biology can be considered as structural science or functional science and since functions are changing structures, they are both structural sciences which researched under the fundamental arrangement of material, energy and the biological law.

Figure 4.5: Skeleton of an extinct dinosaur

Figure 4.6: Crane Construction

According to Otto, 1971 the words of architecture and nature, which can be considered basically different, have surprisingly many similarities in terms of their results. Therefore, the results of these words can be showed that nature crates structures with cells and tissue, with the integrated and single-piece construction. During these constructions its form can be considered as with minimum material expenditure and with the remarkable aesthetic perfection, which can be considered as the similar approaches according to the architectural point of view in accordance with the stylistic notion of the given era.

Therefore, in order to find out the analogy in between the biology and architecture, it is necessary for the scientists to search out the common properties between the biological structures and the architectonic constructions of the forms. According to this analogical principle our task can be considered as to find out the biological properties related to architectonic constructions in order to gain a new bio-technical understanding for the natural forms and functions.

Considering the analogical researches which correspond with architectonic construction, the Open Air Stage at the Olympic Stadium in Berlin, the designers were influenced by any aspect of nature for the modeling of the forms.

Figure 4.7: The web of grass spider, resembling a circus tent

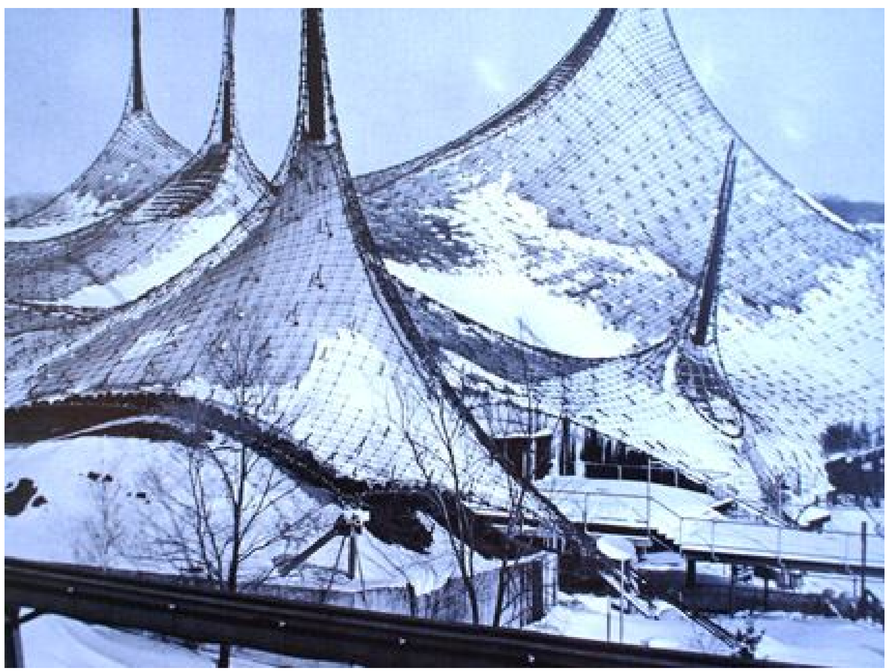


Figure 4.8: The Open Air Stage at the Olympic Stadium in Berlin

According to the IL publication series, 1972 considering the biological development of the natural forms the “morphology” of the construction outlines and the most important constructional relationship still practiced as a kind of art of the organic design. Throughout the development of the segmentation, from the morphological point of view the analogy between biology and architecture has assisted the engineer to find out the relationships, and the better understanding of the architectonic characteristics of the natural and the man-made forms.

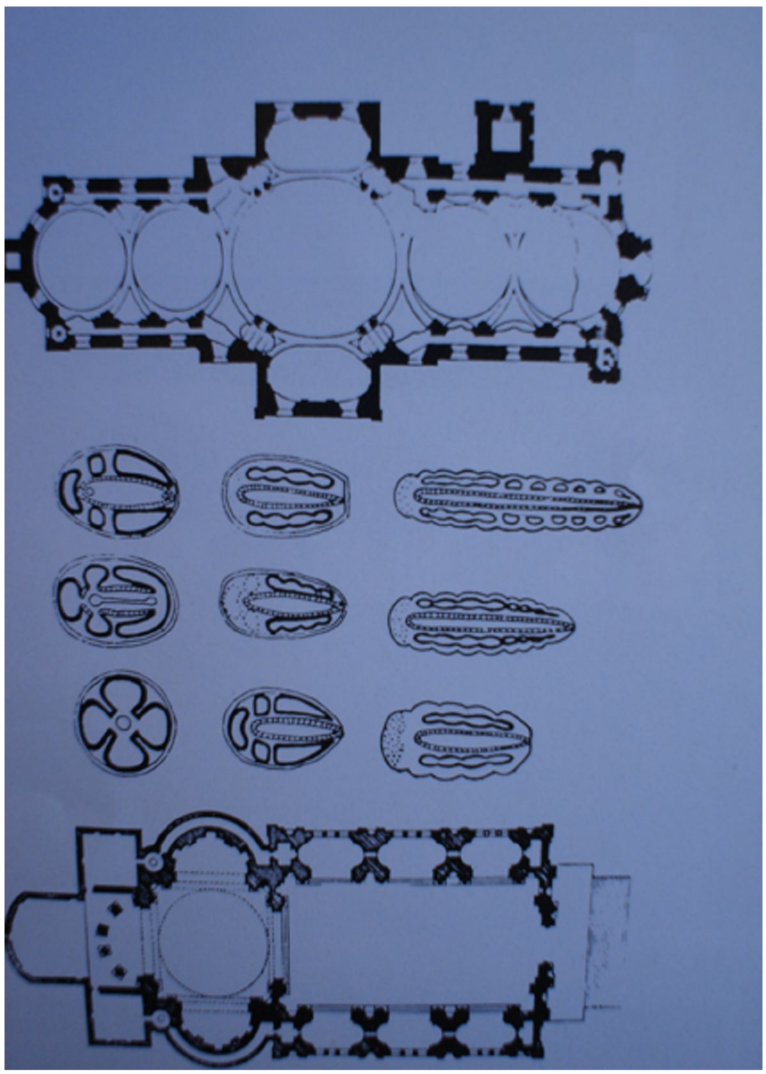


Figure 4.9: The related similarities between the natural and the man-made forms (development of the segmentation)

Considering the above figure; top, plan of the Palladio building Baus il Redentore; bottom, the cloister church in Neresheim designed by Balthasar Neumann, and the middle; scheme for development of the segmentation.

As we discussed in this chapter by reviewing some natural architecture samples and compare them with the man made architecture, we find out that the architecture and design in nature are done in a perfect way which is the optimal way. It means the architectural elements as forms, functions, structures, materials, are in a perfect relation with each other and also the context that they are exist in it.

4.4 Structural Systems in Nature

Every living organism on earth represented a perfectly functioning as well as adapted to the environment as a result of the millions of years of evolution. The structures of biological systems can promote new innovations in architecture.

According to the literature survey Pearce, 1990 mentioned that the natural structural systems can be classified under three different main groups in order to cover the natural structural systems. Therefore, in this system the main principle can be considered as to receive all the external (extrinsic) loads, according to internal (intrinsic) load carrying mechanism in order to achieve the stability of the structural systems.

Additionally, Considering the Pearce's structural systems, 1990 these classifications can be considered as follows:

- (i) System for Diversity, (minimum inventory/maximum diversity principle)
- (ii) Integrative Morphology, (morphological approach)
- (iii) Closest Packing.

In order to understand the concept of these natural systems, it is necessary to understand the development and the infinite variety of the biological systems for living organisms.

Considering the first system which is known as the system for diversity, it can be envisaged which consist of some minimum inventory of components types which can be alternatively combined to yield a great diversity of efficient structural form.

Therefore, this theory presented in such an order to provide a basis for a rapprochement between the principle of standardization and the need for diversity and change in environmental structures. According to this system, the principle of component standardization can be considered as a system of great production and distribution efficiency which conserves natural resources (principle of modularity). Thus, developing the building strategy with which diversity and change can be accomplished by modular systems, the use of natural materials and resources were conserved according to the system.

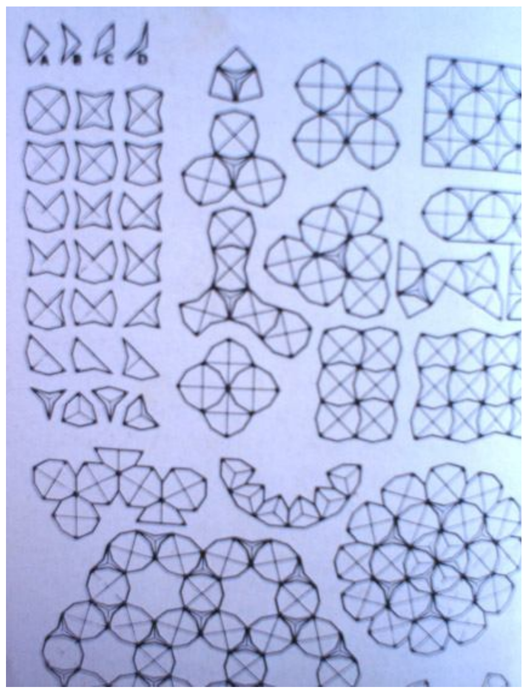


Figure 4.10: A minimum inventory/maximum diversity system.

A geometric schema that exemplifies the minimum inventory /maximum diversity concept related to four geometric modules, A, B, C, and D combined into basic (cellular) units, which is turn form endless varieties by combination and permutation.

According to Bentley and Humphreys, 1962 in an attempt to understand the concept of minimum inventory /maximum diversity system the snowflake can be considered as a most graphic example in nature in order to explanation of the diversity system. Considering this snow crystals, all planar forms are found to have star-like forms with six corners and can be considered as a symmetrical form of a regular hexagon.

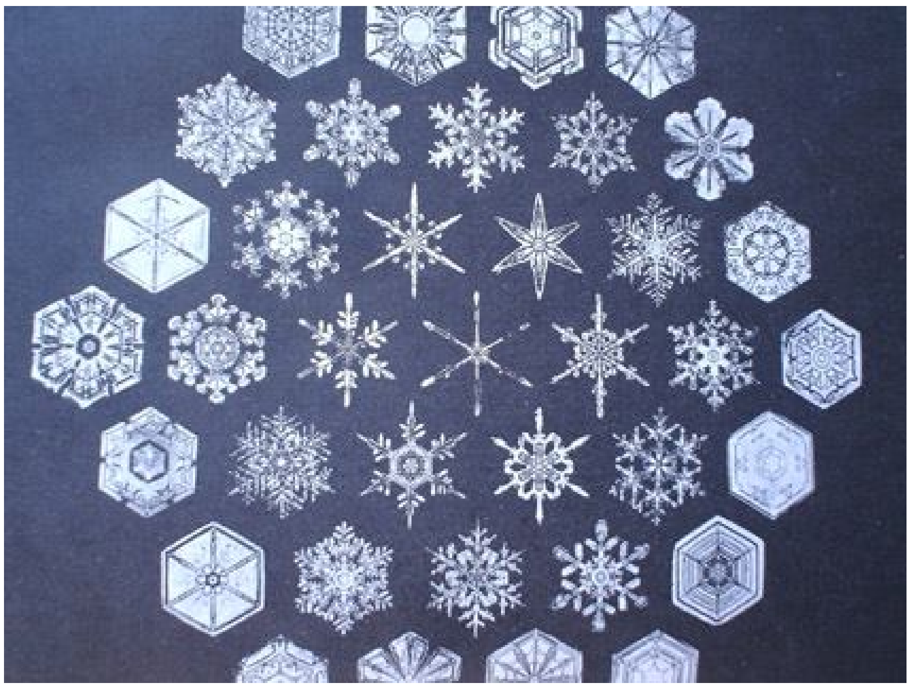


Figure 4.11: Snowflakes exhibit great diversity of form, governed by certain physical, geometrical, and chemical constraints.

The molecular structure of the snowflake can be considered as a building system by which infinite diversity is generated. According to this system, it is interesting to note that each individual snowflake exhibits a high degree of differentiation within its own form and the variety of the snowflake results characteristically governed with the least-energy interactions with the environmental consideration of temperature, humidity, wind velocity and atmospheric pressure under which it is formed.

Therefore as a result of these explanations, an integral part of the concept of minimum inventory/maximum diversity systems can be considered as a principle of conservation of resources (least-energy responses).

Considering the biological structures, the DNA molecules also can be seen under the principle of minimum inventory/maximum diversity systems. Thus, in the present work we are concerned primarily with these aspects of structure in nature which manifest themselves in terms of physic geometric phenomena (built form), since architectural structure operates by definition in this realm.

According to the second type of natural systems which can be considered as a Integrative Morphology, (morphological approach) it can be generated as combination sets of elements which can be represented as modular structures in terms of built form.

Throughout the understanding the systems, considering the forms weather they are atoms, spheres, cells, linear members, or surface, the components of a physical system have specific size, weight, and shape. Therefore, according to Pearce, 1990 the possible ways in which such physical components can fit together into alternative structures are governed by physicogeometrical laws of symmetry. Considering the serious building forms, the fundamental principles governed to enclosure in three dimensions. Since the any volume can be minimally described as a framework, therefore according to the definition above, any finite systems can be defined as some kind of modular framework or network in order to the state of the art of the building design approaches related to exhibition of the forms with an intrinsic forces.

Considering the certain principles of physical structure and a survey of the elementary packing and symmetry properties of three dimensional spaces, the concept of a morphological unit can be expressed in order to move toward a scheme for integrating the array of spatial possibilities into a morphological system of modular structure.

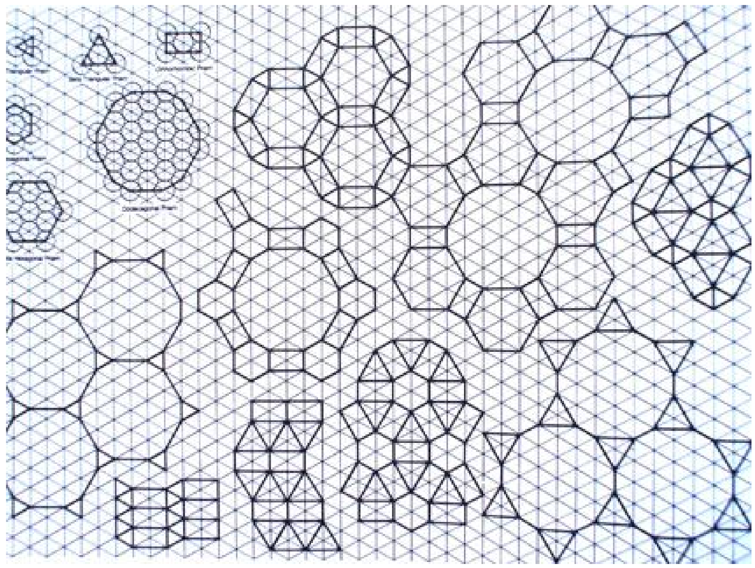


Figure4.12: Hexagonal systems of multiple spaces filling prism on a triangular grid.

The possible common relationship among these explanations has been explored and developed into an integrative morphological strategy since generated as combinations of common sets of elements which govern modular order in three-dimensional space.

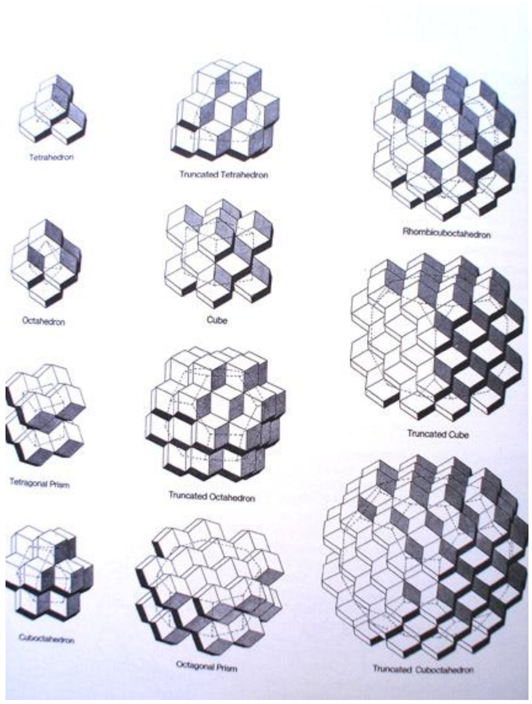


Figure 4.13: The rhombic dodecahedron as a morphological unit.

Additionally, according to the definition of an integrative morphology, in order to find out the three-dimensional ordering principle of this system in nature, the serious modular limitations with respect to the generation of diversity of form can be considered with the intrinsic force system and the physical model systems as well.

According to Thompson, 1963 describes that how nature, as a response to the action of force, “In short, the form of an object is a diagram of forces”. Form as a diagram of forces can be considered as an important governing idea in the application of the minimum inventory/maximum diversity principle to building system design. If a building system can be considered as an analogous to a molecular structure which can be considered also highly responsive to varied actions of force therefore, the possibility of generating building forms responsive to the human needs and natural requirements of diversity, adaptation, change, and the conservative use of natural resources.

Considering the forces in the system, the form of any structure can be considered as with the interaction of two fundamental classes of forces which can be as follows:

(i) Intrinsic forces: Intrinsic forces can be considered as governing factors which are inherent in any particular structural systems. Thus, the internal properties of a system which govern its possible arrangements and its potential performance.

Therefore, in the case of snowflake (snow crystals), the intrinsic force system would be its molecular structure which governs the nature or character of its infinitely varied patterns.

(ii) Extrinsic forces: Extrinsic forces can be considered as governing influences which are external to any particular structural system. They can expressed as the inventory of factors, largely environmental which give direction to the form options allowed by the inherent combinatorial or form-giving properties of a given structural systems.

Therefore, in the case of snowflake (snow crystals), the extrinsic force system would be those specific environmental factors of temperature, humidity, wind velocity, and atmospheric pressure.

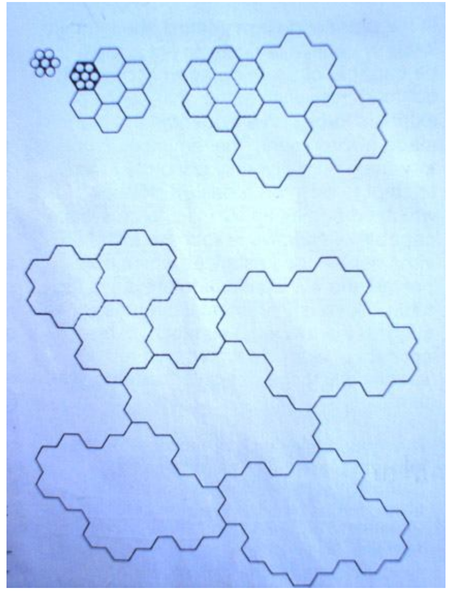


Figure 4.14: A hierarchy of intrinsic and extrinsic forces.

According to Pearce, 1990 all forms in nature are determined by the interaction of intrinsic with extrinsic forces. Therefore, in this system the man-made environment extrinsic forces can be considered the design goals, while the intrinsic forces in the design of the man-made environment can be considered as state of the art. The successful design solutions can be seen only with the appropriate interaction of intrinsic and extrinsic forces.

According to the last type of the natural systems which can be considered as the repeated or iterated pattern of triangles is a pervasive geometrical arrangement in the physical world can be known as Closest Packing.

Closest packing is a structural arrangement of inherent geometric stability that can be expressed in the three-dimensional arrangement of polyhedral cells in biological systems as well as in the dense arrangement of special atoms in the structure of certain metals. Therefore, if the centers of closest packed equal spheres are jointed, a three-dimensional arrangement of equilateral triangles is formed. It can be readily seen that the principle of closest packing is equivalent to that of triangulation and it is well known that triangulated frameworks exhibit inherent geometric stability.

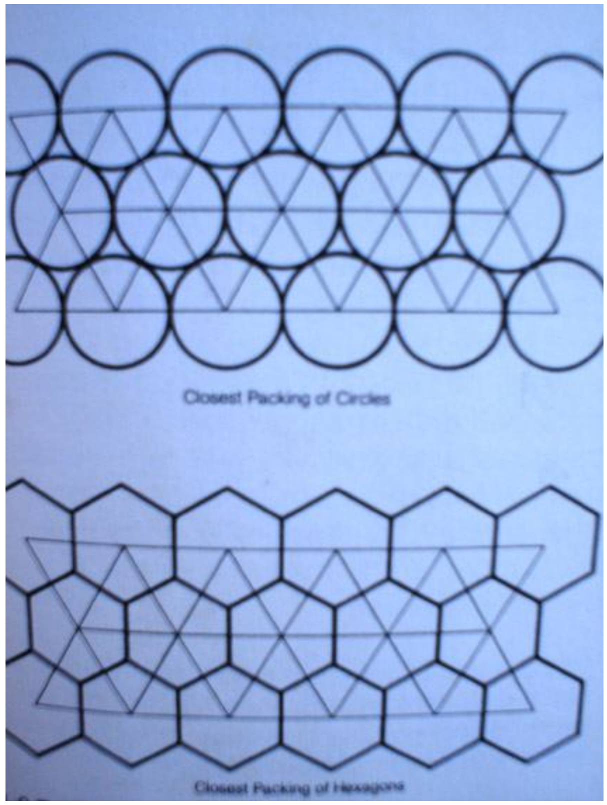


Figure 4.15: Triangulation of two-dimensional closest packed arrays.

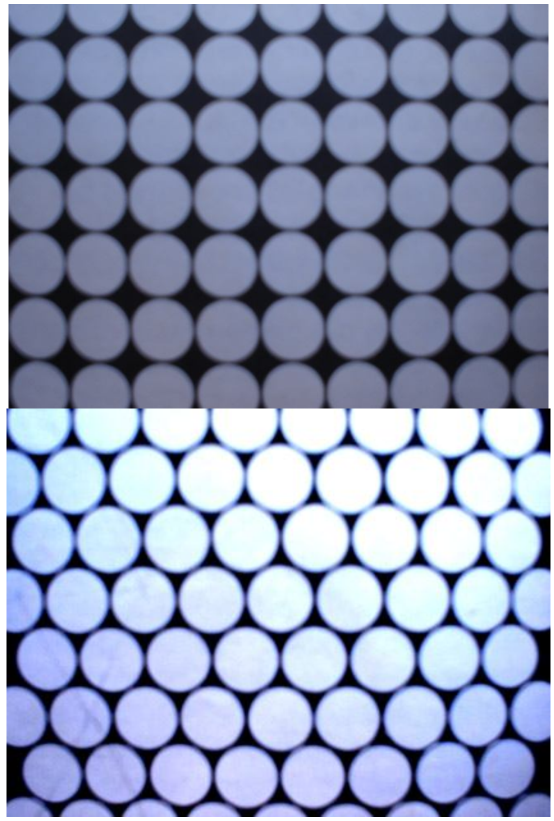


Figure 4.16: Comparison of square and triangular packing of equal circles in a given area.

Considering the natural forms of the bee's honeycomb, can be considered one of the great examples according to the closest packing modeling which required the least energy for the bees to construct (Toth, 1964). According to the cells in tissues or closest packed atoms in certain crystals, if the circles are tightly packed, as densely as possible, and their centers jointed, triangles are formed. Therefore, this can be considered as the arrangement which requires the least effort to maintain their tendency in a triangular order (minimum-energy configuration).

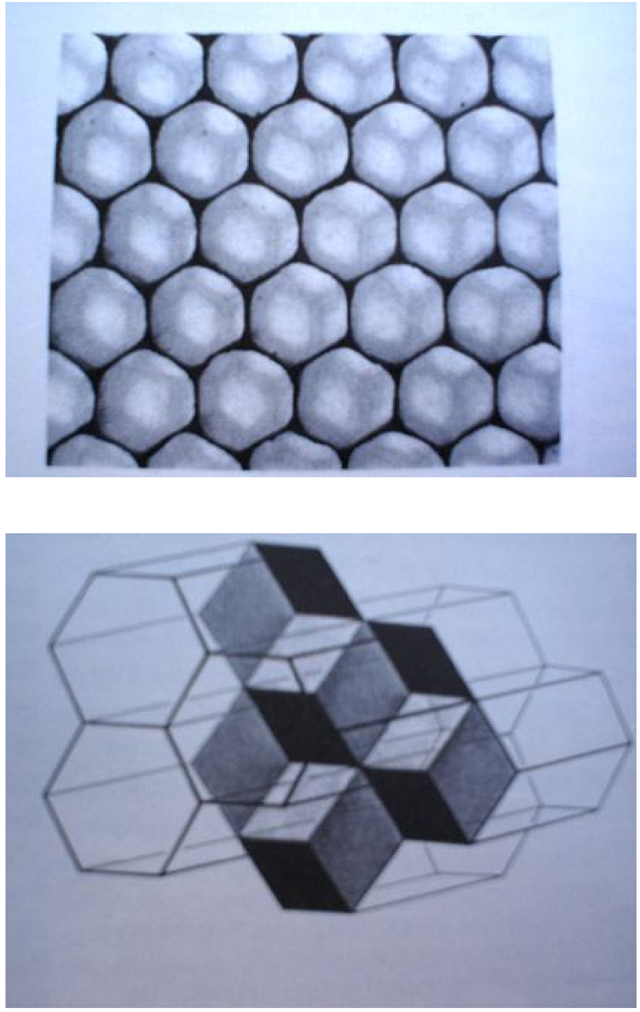


Figure 4.17 Bees' honeycomb. Honeycomb cell structure.

Consider the partitioning formed by closest packed circles, although each circle by itself is very economical the small concave triangles are formed between circles. These concave triangles match the least area with the greatest circumference. Therefore, the circle packing forms cannot be considered as the most economical system, However, considering the concave triangles, forming hexagons this become the most economical method for partitioning a surface into equal units of area.

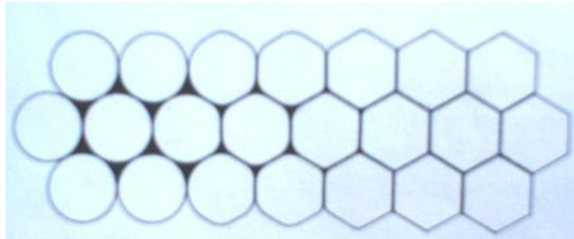


Figure 4.18: Changing closest packed circles into closest packed hexagons.

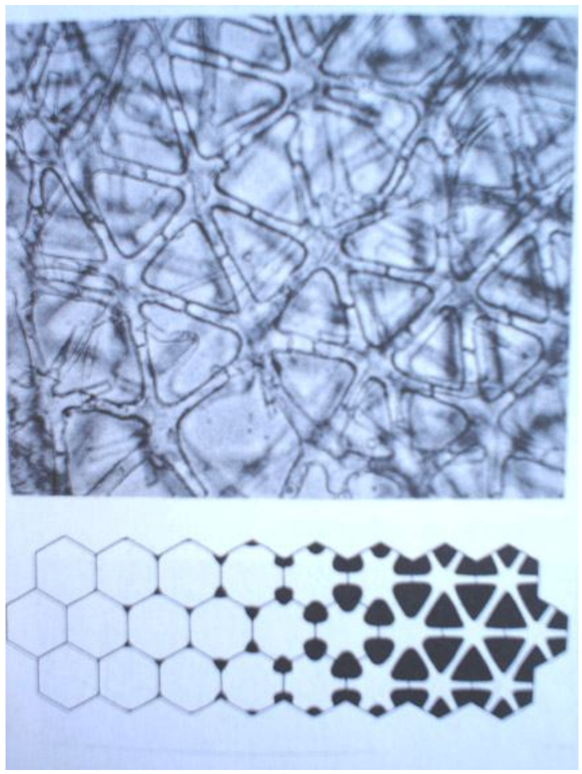


Figure 4.19: Pith cells of the rush. A diagram showing formation of stellate cells upon the collapse of closest packed hexagons.

According to Thompson, 1963 the law of closest packing and triangulation can be seen even in the simple bubble arrays. For any soap bubble array, either random or uniform, at least it can be considered that the cells will be organized according to a triangular order. Triangulation of a planar array of random bubbles viewed.

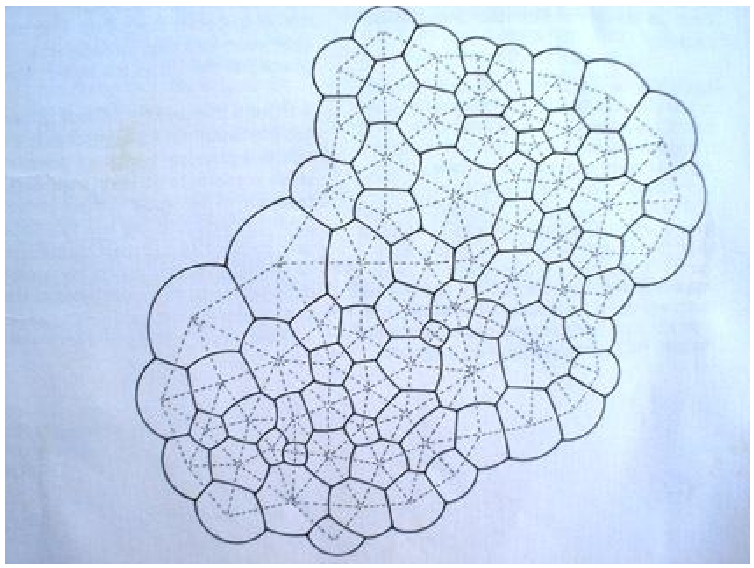


Figure 4.20: Triangulation of a planar array of random bubbles viewed from above.

Considering the structure of the aquatic herb “mare’s tail” (Plant Forms), the related demonstration of hierarchical closest packing of the cells can be seen in a modulated cell.

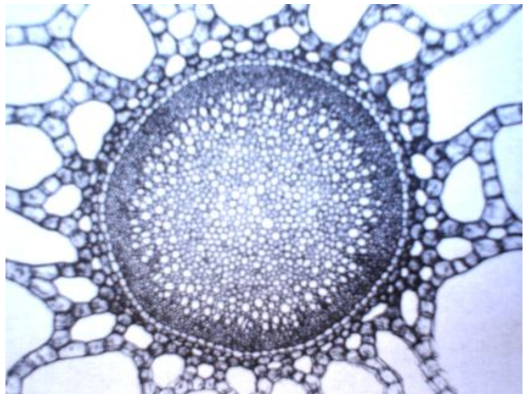


Figure 4.21: Structure of an aquatic herb.

Another example of the closest packing arrays can be seen with the underside of the Boletus mushroom (Plant Forms), which consists of a system of closest packed tubules.

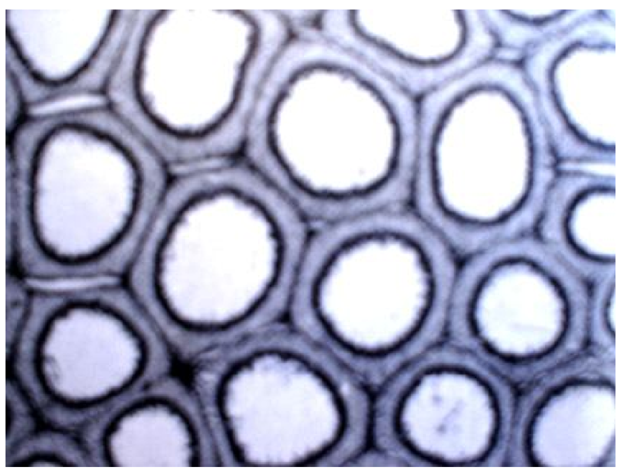


Figure 4.22: Underside of a mushroom.

Considering the animal forms and viruses similar closes packing arrays can be seen at the giraffe and reptile skin. An amusing example of a naturally occurring three-rayed hexagonal network is to be found in the patter of the giraffe skin (Animal Form).

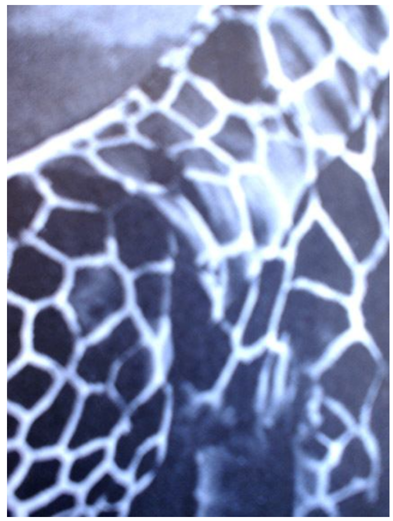


Figure 4.23: Giraffe skin.

Additionally, considering the radiolarian structures which can be considered as a more economical structural solution related to some given set of condition, according to Makowski, 1940 proposed spherical-shell structure based upon the design of the triangulated networks of the Radiolaria (reduction to the practice of the geodesic dome).

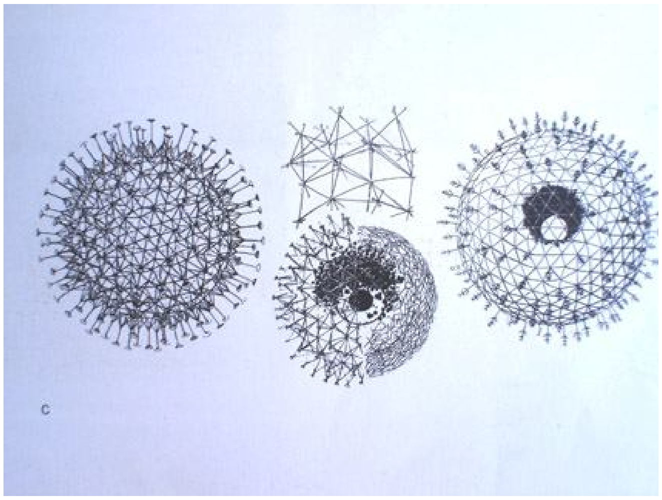


Figure 4.25: Spherical radiolarian skeletons.

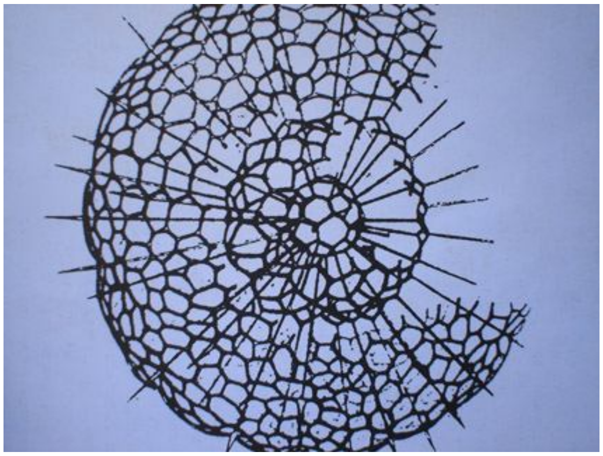


Figure 4.26: Skeleton of the radiolarian, Haeckel, 1887

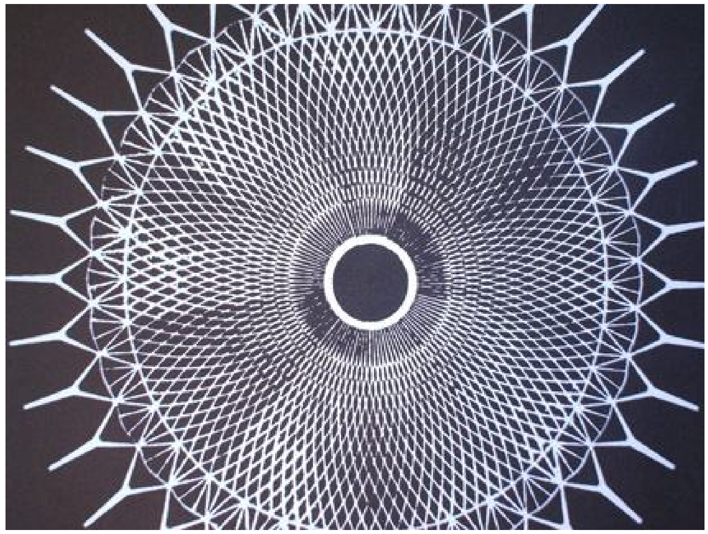


Figure 4.27: Plan of the dome and its supporting struts, small sports place, Rome (Nervi).

As we discussed above the structures in nature are in optimal way from different point of view, the material are used enough with the highest stability against the forces, like our bones which are empty from inside but because of their shape they are stable against the internal and some external forces. Such and structural systems are many in nature and as an architect if we could have same systems in our buildings and designs we can save material and create more stable structures and buildings.

CHAPTER 5

ARCHITECTURE BY INSPIRATION FROM NATURE

5.1 Introduction

Architectural and structural design is in a fascinating period of significant changes, both of quantitative and qualitative nature. These changes are mostly driven by progress in computer science and in design and inventive engineering and architects. Growing computational resources available to engineers and designer yield quantitative improvement to the analysis and optimization of complex structural and architectural systems. Better understanding of the design process, especially of it's of its conceptual stage and the development of various computational models for the generation of design concepts, create a potential for the fundamental qualitative changes in architectural and structural design, in which design novelty will be controlled and adjusted in accordance to needs.

The history of our civilization clearly demonstrates that progress in engineering and architecture is always driven by demand for new systems. This demand is shaped by the rational needs and by our ambitions and dreams. The combination of rational and emotional reason is very potent. It forces architect and engineer to look not only for incremental improvement of their designs but also to search for novel designs responding to the emotional needs of our societies. The monument of our civilization, bridges, tall buildings, exhibition halls, etc, always represent the state of the architecture in structural engineering, but the also reflect the emotional dimension of our profession. Architecture and engineering progress is often driven, or at least strongly influenced, by the emotional factors related to the competition among nations or among communities, like building cathedrals in the middle ages or tall buildings or bridges these days.

Our monuments are products of rational thinking, systematic analysis, design and optimization. However, they would never be created without inspiration. It encourages architects and engineers to change their design paradigms and to create novel architectural and engineering systems responding to ever growing architecture and engineering requirements and to the emotional needs of our societies. Recognizing the importance of inspiration in design and the relationship between inspiration and design creativity is crucial.

In this chapter some architectural designs which are got some ideas or some solution for their designs from nature will be discuss under through three level of inspiration. In this section we trying to find out that the architects who are inspiring from nature are looking to which point are they usually getting idea forms, function, structure or material, in the other work we consider them as and visual or conceptual or computational ones and analysis of the sources of inspiration as an evolutionary, co-evolutionary, cellular automata, and Triz will be in the future studies.

5.2 Architecture from Nature to Nature

As we discussed in evolution of architecture the buildings development are following the same line with the technology and machines. The machine has been the symbol of progress and mankind's mastery over nature for the last hundred years. It is not surprising that machines are the ultimate metaphor for the buildings of today. Le Corbusier, one of the 20th century's greatest architects even went so far as to say that, "houses were machines for living in."

Our buildings like the machines are getting more and more regardless of culture and nature. Unfortunately, like the machines of our age, our buildings use energy and materials wantonly, depleting resources and using energy. The root of the problem was our shortsighted belief that technology combined with a great deal of energy was the answer to any design problem.

As it can be understood from what has been discussed above, nature has not been considered in solving a design problem as before; in pre-historic era there was a stronger relationship between nature and man-made environment; but in the later periods, this connection became weak and sometimes completely lost.

Throughout human history, nature has been the inspiration for many forms in the visual arts and architecture; from the time of early civilization, as in Egypt, similarly in Greek and Roman architecture. Natural patterns provided inspiration for increased knowledge of mathematics and science. As man struggled to understand his world he observed nature and learned from it, and used it accordingly. This is most easily seen in more primitive communities where everything is made by hand from the materials available, and decorated with specific motifs from the natural surroundings that they know so well.

Architecture is no different in receiving inspiration from nature, and it often goes deeper than imitating just the surface features of nature. Some architects have explored the architecture of trees, for example, the roots, structure, branches and delivery systems to design buildings that utilize the same efficiencies. The structure of cantilevers copies natural features and the aesthetics of structural design look more stable if they relate visually to a natural phenomenon that we intuitively think of as being strong and stable. In architecture like the other sciences and fields some designer tries to get their idea from nature and as it goes to future they feels that they should come back and be more close to nature for their design idea. There are few samples that they have their idea either from the formal point or structural point or the functional point.

5.3 levels and Sources of Inspiration from Nature

At least three kinds of inspiration can be renowned in architecture and design, and each kind plays different role. All these three provide a spectrum whose understanding is critical for the progress in design. These three levels of inspiration are named as visual, conceptual and computational; in this study we work more on the first two levels and we are not going through the details of the third one.

Visual inspiration is relatively well understood and widely used. In this case, picture of various living organisms, or their system, are used to create similarly looking engineering systems. For example a picture of sea turtle shell can be used to shape a reinforced concrete for a large span roof structure in an exhibition building. Visual inspiration can produce useful result especially in architectural design from the aesthetic points of architecture. Unfortunately, it requires the involvement of a human designer who knows structural engineering and the theory of elastic shells, and who is able, most importantly, to avoid using inspiration in a wrong context. In such a case, a visual can be incorrectly to produce a dangerous design. For example, the use of the same sea turtle shell shape (Figure 6.1) to design a shear wall in a tall building may result in a structure excessively sensitive to large vertical forces and may be ultimately dangerously unstable.

Figure 5.1: turtle shell in nature

Figure 5.2: Exhibition hall inspired from turtle shell

Conceptual inspiration occurs when a structural engineer uses a principle found in nature in design, for example, the biological principle of homeostasis. This principle states that any living organism reacts correspondingly to recover its vital functions when attacked by an external agent. A designer can apply this principle, for example, to determine the optimal shape of shell roofs subjected to thermal and mechanical loads. Unfortunately, using conceptual inspiration requires a solid understanding of both nature and structural engineering and cannot be used in a mechanistic way by an automated designing system.

Visual inspiration is skin-deep. Conceptual inspiration is abstract and difficult to use. In fact, both require the involvement of a sophisticated human designer. Fortunately, the third kind of inspiration, called here computational inspiration, is the most promising from the perspective of automated conceptual design. It is the most intriguing, still poorly understood and difficult, but has the greatest potential to revolutionize design. In this case inspiration occurs, on the level of computational mechanisms, which are inspired by the mechanism occurring in nature. Such mechanism will not be discussed in this study.

5.4 Inspiration from Nature in Architectural Design

5.4.1 Visual Inspiration Architectural Example

According to the definition of visual inspiration in above the buildings and the design which are got the inspiration from nature by the cisual principles like forms can be added to the category of visual inspiration. Ascent at Roebling Bridge, Cincinnati, Kentucky as shown in figure 6.3 can be one of these examples. This residential building was constructed by Daniel Libeskind; it reflects the architect's goals in relation to bionic architecture. The sloping curved roof takes design cues from the natural environment and also offer residents of the building an uncluttered view of the city. The natural tones of the building were specifically chosen to reflect the earth and sky of the area. It provides a dynamic addition to the skyline of the greater Cincinnati area and is a dramatic departure from the surrounding waterfront buildings.

Figure 5.3: Ascent building at Roebling Bridge in Cincinnati, Kentucky done by Daniel Libeskind

City Hall in London has some formal inspiration from the nature. This design comes from Norman Foster's firm Foster and Partners, who believe that the world can be changed by changing the design of the places in which we live. This building is intended to represent and inspire the forward motion of the democratic process in London. It is a mostly non-polluting building, constructed of sustainable materials.

Figure 5.4: City Hall done by Norman Foster in Londan

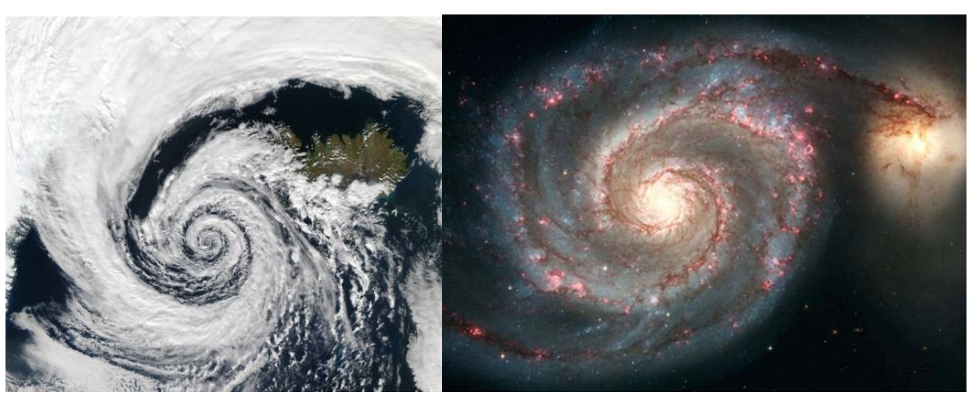


Figure 5.5: The spiral form in nature

Denver International Airport is another example of this kind of architecture. Denver The tensile fabric roof of this building is designed by inspiration from the naturally occurring beauty of the Rocky Mountains. As the largest airport in the United States, it reflects a mixture of historic and modern architecture.

Figure 5.6: Denver international airport in USA

Figure 5.7: Natural rocky mountain

Selfridges Building in Birmingham, by architect Jan Kaplicky, founder of Future Systems, features a curvy space-age design that epitomizes what the aesthetic goal of bionic architecture is all about. His idea was to combine the organic and natural forms with high technology to achieve the optimization. Completed in 2003, it remains one of the leading forward-thinking buildings out there.

Figure 5.8: Bullring in Birmingham done by Jan Kaplicky

Figure 5.9: Wasp nest structure

Floating House in created by Robert Oshatz Inspired by Nature, Taking inspiration from ocean, the end result sits in harmony with its surroundings. Oshatz is known for his curvaceous, swooping architecture and unique approach to design. Since active construction is prohibited on the Willamette, Oshatz had to construct the home off-site on the connected Columbia River and pull it by barge to its mooring. This unique home is kept afloat by locally sourced 80-foot Douglas fir logs, and the exterior design takes its cue from ocean waves.

Figure 5.10: floating House and its natural concept

5.4.2 Conceptual Inspiration Architectural Example

Ark of the World, Costa Rica is the example of inspired design. The buildings created by Greg Lynn are based on a type of architecture for which he coined the term ‘blobitecture‘. This type of building relies on the ‘blob-like’ shapes of amoebas and other naturally occurring forms to create the basic bulbous (rounded) design of the buildings. One of the best examples of this is his plans for the Ark of the World, a building located in the Costa Rican rainforest which is planned to serve as an eco-center and location of eco-education.

Figure 5.11: Costa Rica done by Greg Lynn

Figure 5.12: water blob

A tensile fabric roof serves as a platform for people interested in looking out over the rainforest and a column-based water garden keeps the place cool. The design of the building itself appears floral in nature, which is pretty damn cool.

Urban Cactus in Rotterdam is a 19-storey residential building, shaped in a way that is inspired by an irregular pattern of outdoor spaces. Natural sunlight and a unique design on the harbor give it the semblance of bionic architecture and of course it’s interesting and curvy aesthetics make it an appealing building. However, it’s not 100% green or sustainable; therefore it only gets an honorable mention on most bionic architecture lists.

Figure 5.13: Urban Cactus in Rotterdam

Figure 5.14: irregular pattern of outdoor spaces

Beijing Olympic Stadium, by Swiss architects Herzog and de Meuron houses a 91,000-seat arena under its 12-metre-deep steel exoskeleton, Inspired by Bird Nest because of its tightly woven lattice structure.

Figure 5.15: Beijing Olympic Stadium and natural nest

The Aqua Tower by Studio Gang Architects in Chicago, The building promises a sculptural shape reminding the geologic shapes from the great lakes region. Aqua tower considers criteria such as views, solar shading and function to derive a vertical system of contours that gives the structure its sculptural form. Its vertical topography is defined by its outdoor terraces that gradually change in plan over the length of the tower. These terraces offer a strong connection to the outdoors and allow inhabitants to occupy the building façade and city simultaneously. The result is a highly sculptural building when viewed obliquely that transforms into a slender rectangle from further away. Its powerful form suggests the limestone outcroppings and geologic forces that shaped the great lakes region.

Figure 5.16: Aqua tower done by Studio Gang Architects in Chicago

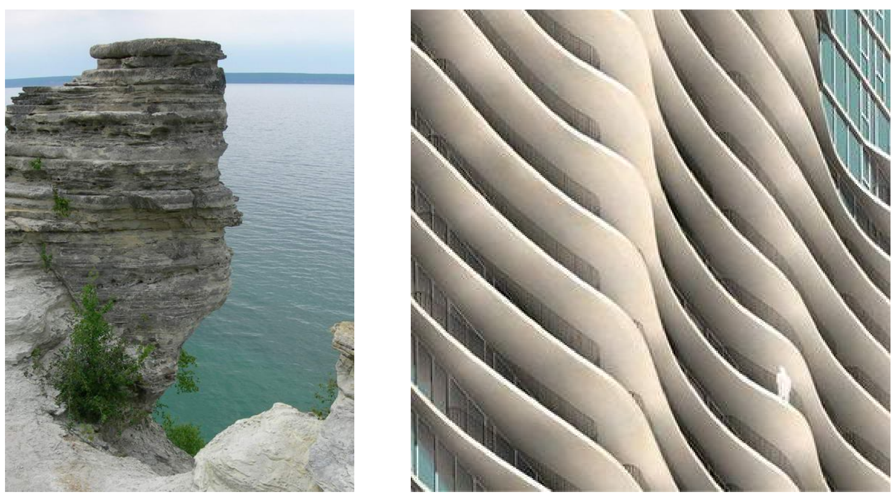


Figure 5.17: Limestone in nature and façade detail of Aqua tower

5.4.3 Computational Inspiration Architectural Example

We can mention to Anti-Smog building in Paris as one of these examples which is done by Vincent Callebaut who is making some serious waves in the world of bionic architecture. It's a mixed-use building, erected over abandoned railroad tracks in Paris and turns it into useful recycled energy resources. Natural lagoons, as well as a rooftop view of Paris are both bonuses that make people want to spend time in this eco-friendly building. And are designed using green technologies that actually suck the smog from the streets of it reflects the architect's goals in relation to bionic architecture. The natural tones of the building were specifically chosen to reflect the earth and the sky of the area.

Figure 5.18: Anti-smog in Paris done by Vincent callebaut

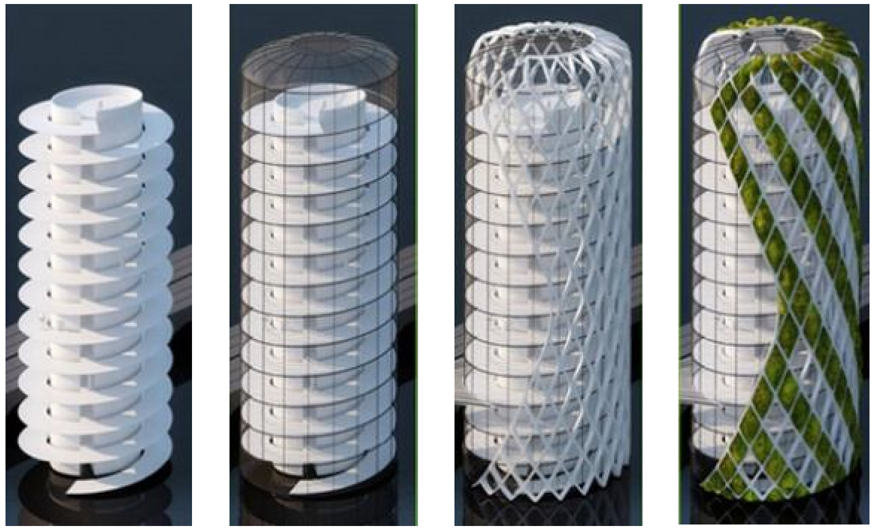


Figure 5.19: Design process of anti-smog building

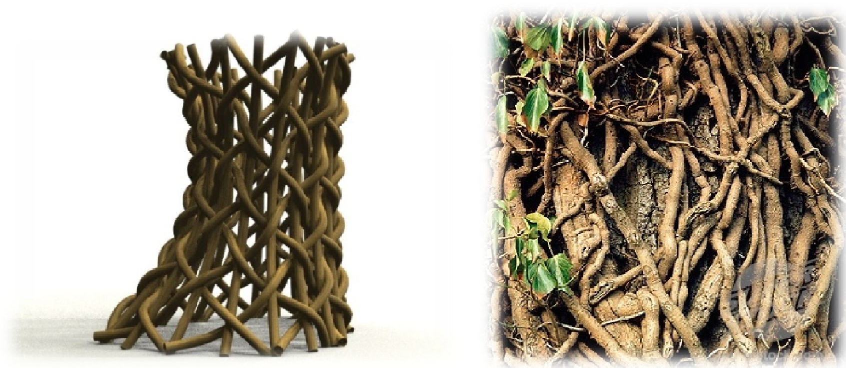


Figure 5.20: tree roots structure

Leading architect William McDonough shows his commitment to creativity, intelligent building and designs that feed ecosystems. As the name suggests, this is a skyscraper that has been designed by the inspiration from the growth and change of a tree. A curved, aerodynamic building, reducing the impact of the wind, it uses minimal construction materials, while making maximum use of the enclosed space. All of the water in the building is recycled in a manner similar to that of how a tree would re-use water and nutrients. Wastewater from sinks flows into the building's three gardens and the water from the gardens is subsequently re-used in the toilets. it uses solar electricity (the southern façade would be made of about 100,000 square feet of photovoltaic panels that convert sunlight into electricity), And is made completely of recyclable materials. McDonough's proposal focuses on the possibilities of today, for a future context, integrating green and arboreal-inspired systems in a super efficient, forward-thinking architectural marvel.

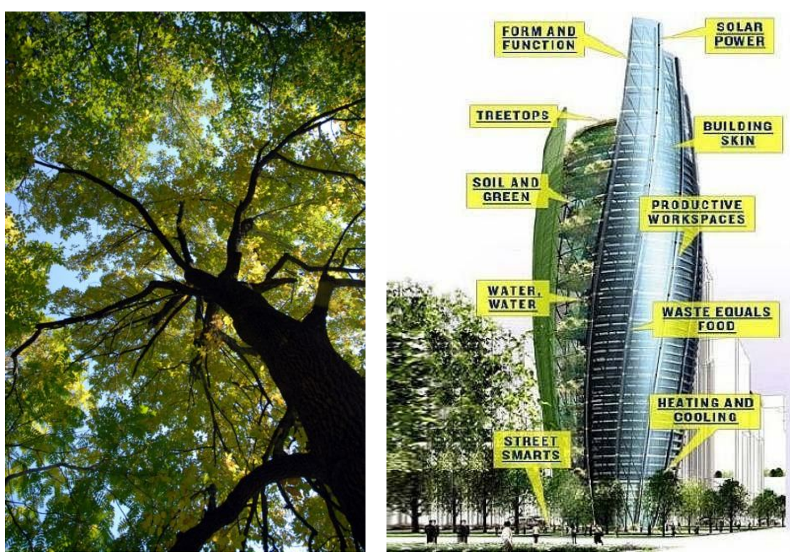
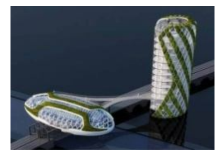
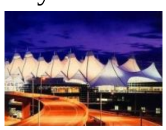
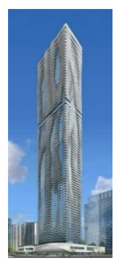


Figure 5.21: Intelligent building done by William McDonough

Some samples of inspiration architecture from nature had been discussed above and it has been shown that some architects are getting some design idea from the nature. Some of them are getting idea for their form creation, some are getting idea to solve their structural solution and some of them are using the materials by getting help from the nature and according to the table 5.1 we can see the number of architect who is getting inspiration from nature by the level of visual inspiration is more than the one who is using the conceptual level and these two are more than the computational ones. But the architecture in nature as we discussed before are optimized in different section the design in nature are done by the perfect relation between form, structure, function, material and the context which is exist. In all of pervious example we cannot feel these relation, they only got idea for some or one section it means some architect are using the natural solution for structure and some for forms but they are not using them as all.

Table 5.1: level of inspiration

Visual	Conceptual	Computational
 Ascent building	 Costa Rica	 Intelligent Building
 City Hall	 Urban Cactus	 Anti-Smog Building
 Denver Airport	 Beijn Stadium	
 Bullring Building	 Aqua Tower	
 Floating house		

CHAPTER 6

CONCLUSION

As it has been study in previous chapters, there is a debate among a group of scholars, which the nature would be accepted as reference for architecture too or it would be a part beside it.

To achieve the aim of the study a short review took place, all through the history, from the time that human were line with the nature up to the time that human hurts the nature right after the industrialization.

Accordingly nature has been a part of architecture from the time that human directly used it by living in the caves and using building material according to the nature of its surrounding up to the time after industrialization which the perspective has been changed by the new materials, tools and technologies and inspiration of nature took place in architecture.

But it is not all what architecture took from nature, by short look to the development of architecture, form, function and space quality and some of the main factors which has been taken to the consideration, all through the history of classic architecture, and has been extend up to today's architecture. All of the mentioned factors are under the influence of environmental factors started from gravity up to the earthquake and thermal factors which are common point in the medium of the nature.

In this case all other creature in nature are struggling with this factors and by the help of the evolution, were find best and most effective way of facing with this factors is in nature.

However the best way of facing with gravity is to face with it by inspiring from natural structure base on this study, but there are facts beyond this which take inspiration from nature to have most optimized architecture as optimization in nature, to face with new restraint, and limitation of resources, beside being in harmony with nature as medium we are living in.

The study has intended to show new approaches to have new era of architecture, by taking inspiration from nature in different perspectives.

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