

Architecture as an Organism

M.R. Bemanian, M. Ansari and M. Yeganeh
Department of Architecture, Faculty of Art
Tarbiat Modares University
Iran

Abstract

From the time immemorial, human beings have been accompanied with the nature and natural organisms. During this course, human beings change gradually from thoughtless consumer to technical and technological existence. These interactions sometimes lead to different and contradictory paradigms but the natural organisms have always been the inspiring sources for humans. Like other human beings, architects enjoyed such an inspirations and criteria as well [Lang, 2002:40]. However, they necessarily not always successful as degree of their success depended upon their perception and understanding of the nature of organisms. Later, some biological comparisons were introduced focusing on formal and structural aspects to have wider perspective about the nature of the organisms and new rules and regulations. These gave rise to critical faults and disadvantages.

The present work attempts to introduce some of the principles, rules and regulations related to the natural organism and then describes how to apply those organisms in architecture.

Keywords

Rules of nature, Inspiration, Mimicking, Sustainability, Comparison.

1. Introduction

During the course of history, human being endeavored so that they can dominate to nature and acquire advancements [Fig1]. This domination has any damages for nature and human beings in many cases. Initially man was under the direct influence of nature and their whole living patterns were dominated by nature. Human beings always try to safeguard their needs i.e. security and survival. Gradually man is incapable of adverse patience and intends to coordinate nature with them or vice versa. In next process man intends to maximum benefits from the nature and lays ground to damage the nature. Similarly, comfort impulse also existed in recent but understandings to environmental damages have gone up. International community has planned industrial adaptation to the environment.

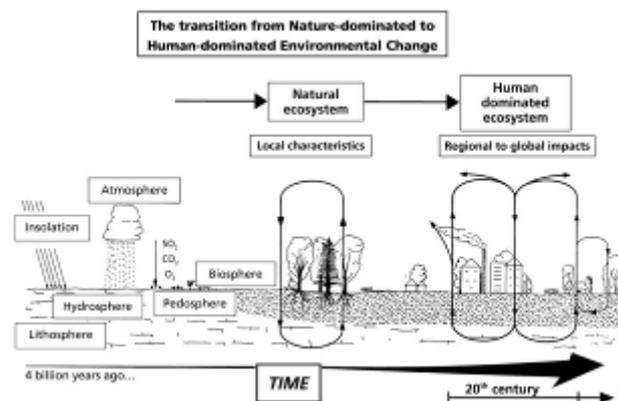


Figure 1: The time-line of environmental change (Ganssen, 1965; Schreiber, 1980; Messerli, 1986): Natural ecosystems are characterized mainly by locally adopted and integrated processes in contrast to “urban-industrialized ecosystems”, which have a growing and far-reaching impact on air, water and on a regional to global level(Messerli& et al 2000: 460)

Like other human beings, architects attempt attention to nature in architectural design and built process. Architecture is formed under the influence of many elements that are largely divided into the human environment and the physical environment. Moreover, elements that complement each other influence the architecture (Rapoport, 1969). Architecture needs to be harmonized with nature, thus nature should not be considered as a challenge to be overcome. In many traditional architecture of countries, in them approach to harmony with nature have formed unique architectural cultures. It appears that contemporary architecture

seems to have lost the capacity to control the architectural environment itself (Kim, 2006:1906) by the end of previous century; a pro –environmental architecture trend began to appear. Although, networks and new methods today propounded in conforming and adapting architecture with nature as recent architecture attempts to model with nature but naturalism has been merely in its form and has led to the emergence of imaginary environment [Hamzenejhad,2006:31-40].in addition of mimicking method from nature in architecture, inspiring of natural organism and metaphoric perception of them also understanding rules governing in natural organism especially living natural systems and use them in architecture can be useful in building.

2. Comparison of Biological Architecture

Architecture being important organism has attracted much attention with the usage "biology" in the early 19th century by "Lamarck". Primo Levi Italian chemist indicate that “Whatever takes place in chemistry is similar that take place in architecture. Whatever takes place in molecules same occur in Cathedral dome or arch of bridge” (Levi, 1986). Ruskin expressed that “Never mimic anything unless from natural forms” [Ruskin, 1906:247]. Generally, the important biological reality with regard to modern architecture was the relation between form and function. This expression that "form follows function" or "function follows the form" was first brought up in biology[Collins,1998:120-126] and debated for more than half a century. And this eased the propagation of biological analogies because the only way to compare architecture and the city, from the body point of view, with a living creature is to rely on the relation between form and function. The other expression, which has been borrowed from biology in architecture causing discussion on form, shape and relation, is the word "organic" that can be used in studies and researches about the structure and skeleton of animals and plants. The biological discussions interpret the relations of small parts to the same organs that create a thing [Ibid: 126-130].

The beginning of such biological analogies can be attributed to "Wright" and "Sullivan". While "Sullivan" first put forward these analogies, "Wright" created a kind of organic architecture by designing non-symmetrical plans[fig2], creating movement, using the environment’s materials, and composing the architecture with the nature According to him, organic architecture has to be devoid of useless and superfluous forms [Aguar, 2003:77]. Biological analogy that expresses "form follows function" is one of the most fundamental bases of theoretical functionalism in modern architecture. However, it has ever been formal and substantial who's every organ is compared with the other, without paying attention to the soul and concept inside the organ. The structural designs that occur in nature—in molecules, in crystals, in living cells, in galaxies—is the proper source of inspiration, can affirms, for the design of man-made structures. Principles governing in natural organisms lead the designer in this "natural" direction, beyond the familiar limitations of the right angle and the cube and into a richer world of forms based on the triangle, the hexagon, and general polyhedral, as well as saddle polyhedral spanned by minimal continuous surfaces [Pearce, 1980]. Nature at all levels builds responsive and adaptive strategies that conserve material and energy resources through the use of modular components combined with least-energy structural strategies [Ibid].

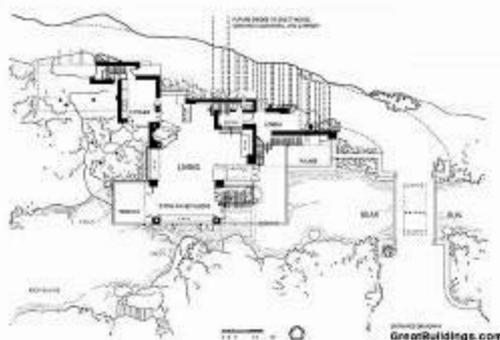


Figure 2: “Falling water House” is a lofty sample coordinated with nature and architecture (Wright, Pennsylvania, 1934, 1938, 1948).

3. Patterns from Natural Systems in Architecture

Investigation in biological architecture express that inspiring from natural organism are usually in three ways as mimicking from nature, metaphoric inspiration from natural structures and patterning from rules governing to natural organisms.

Mimicking patters: In this type of patterning imitation, there is no attention to fundamentals of structure. For example the earth's layers can form the forces that affect it and take its form while the architects omit these forces and use just the layers forms.

Metaphoric patters: Here, an abstract form of nature is used for equilibrium and sustainability [fig3]. Metaphor keeps us from being superficial towards extents and we know it as a way towards creativity in architecture [Antoniades, 2002:63].

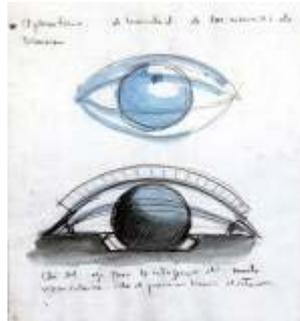


Figure 3: Metaphorical inspiration from eye in architecture (Calatrava, 1996, the City of Arts and Sciences complex, Valencia, Spain).

Patterning from natural systems rules: recognizing rules in living natural systems and application them in architectural design is one of the ways by the architects. In Sundial Bridge at California [fig4] Calatrava utilized symmetry of birds and their changing capabilities and movement and also resistant ad durability rules against any forces with utmost professional way in his projects [Mort, 2009]. It is built with steel, glass and granite and appears to cantilever over the water, protecting environmentally sensitive areas and salmon habitat. There are actually viewing platforms at both ends, giving visitors a variety of vista points from which to see this marvel of design ingenuity [white, 2006].this project can be both metaphorical pattern and Patterning from natural systems rules. Inspiration for this project where influenced by Puente Del Alamillo with the fling bride and the skeletal form of his once pet dog being at the forefront of his ideas.” Nature is believed to have some of the most functionally efficient forms and so Calatrava uses this to produce magnificent works of art form everyday sights and experiences” [Mort, 2009].



Figure 4: Calatrava, 2004, Sundial Bridge, California

Left: utilized symmetry of birds

Right: and their wind's resistant against wind and other forces with utmost professional way

4. Rules Governing on Natural Organisms and Way using them in Architecture

Correct use of design rules is in a way that probably there may be no formal similarities between organism's structure and building. Thus we must look into the essence of organism and rules that dominate them. Here, we bring some natural orders that are used in architecture.

Behavioral method against forces

The behavior against the imposed forces and loads is one of the most important reasons of existing structure. The strategies of organisms against these forces are so interesting and make one think deeply. In architecture too, we can find so many using these strategies. Aspects related to Behavioral method against forces can discern in static and dynamic phenomena. Evading bending stresses can be carried out in a static construction, whereas evasion is a dynamic strategy.

a) Static strategies: Resisting the forces by pressure and tensile stresses and evading bending stresses are the usual way of the structure resisting by bearing the stress in its parts. Attention to the type of stress is useful in making the structure more efficient.

Organisms always try to make use of compressing tension stresses to the larger possible extent in their structures and use bending stresses merely if structures possess layer essence. The gradual perfection of

structures from bending towards compressing and tension like tents and shells is in this direction. Designing buildings that can less absorb of horizontal and vertical forces are kinds of this task.

Use of obtrusive forces against each other or against themselves is seen mostly in plants. As an example, during windy hour trees store some of the wind energy in their stems and release it during the fluctuation in the movements. This strategy is often seen in traditional architecture that is defined as "contradictory forces" that we may see in neutralizing the forces of vaults [fig5].



Figure5: balance of great vault by contradiction of forces in “Sasaniyan” period of Persian architecture (Iraq, Ivan-**E** -Madaen)

Flexibility and deformation in order to resist the forces in natural structures is much obvious. It is for this reason that birds build their nests on fragile and flexible branches. Using structures with less materials and more flexible is the example of those architectural works. In order to minimize the amount of forces affecting the structure, natural structure especially plants respond with bending to natural obtrusive forces. However, there is very less probability of reaching to this phenomenon. Still, the reflexive buildings that take aside against external forces have not been observed. In nature structures are conformity to transformation path of forces. Pier Luigi Nervi (1891–1979) was inspired from structure of Sunflowers [Fig6-left] in the built for the Italian Air Force [Fig-right]. In this building structure of roof was shaped based on Isoeostatic curve lines that have maximum tensions.

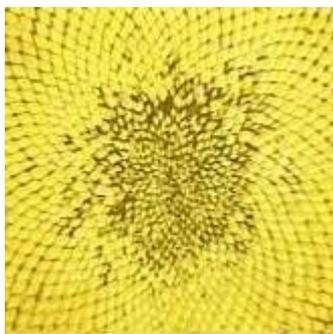


Figure 6: Left: Sunflower structure has resistant structure that based on Isoeostatic curve lines rule. Right: Form has shaped based on Isoeostatic curve lines (Nervi, 1932, Orvieto Italy, Italian Air Force)

Another example for coordination between form and forces is form of marine asset. Bivalve sell has a folded structure that can be resistant against bending forces [Fig7-left]. Folded plates structure in architecture can be inspired from these forms [Fig7-right].



Figure 7: Left: Bivalve sell Right: The roof structure is a combination of an arch system and a concrete folded plate system. (Brooklyn – McCarren Park Aquatic Center, Jeremy Carvalho, 2008)

b) Dynamic strategies

Natural design is done by load weighing and correction cycle. In an area where strong winds blow; roots of plants generally grow thicker against the direction of wind. In the form as well, plants grow in conical condition and their stems during the growth, bend towards the direction of wind. On the rear side of wind, rings of the trees are more compressed whereas on the opposite side they are more tensile. In the other words, environmental structure compare to the mechanical tensions especially effect with the wind [fig8]. Mobile structures of Calatrava or dynamic structures can be named for these kinds of buildings. Flexibility in many natural forms is visible. In complex life

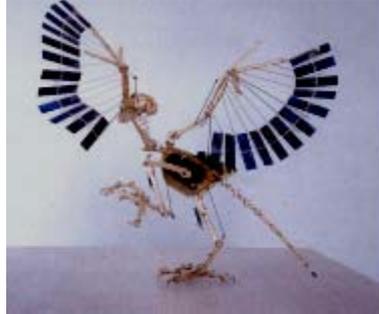


Figure 8: Symmetrical movement of living beings can benefit in symmetrical construction of mobile architecture

Oneness structure and material: In nature there is no clear cut between material and structure. In architecture, pyramids of Giza Egypt [fig9] and Yokohama Port Terminal are good examples of this aspect.



Figure 9: integration between structure and space, correlation between structure and material in the Great pyramid of Giza

Integration between all parts in natural organism is understandable. Example for integration between structure and material in nature is natural stone arches that transfer pressure loads in the best way. Theses natural structures instance The Rainbow Bridge [Fig10] in Arizona and Landscape Arch in Utah are the sources of some architectures among Utzon in designing of Sydney Opera House.



Figure 10: Rainbow Bridge in Arizona is the largest natural bridge in the world

Organisms have the best structural form with the least amount of materials. Materials used on the basis of performance and conformity with natural forces and in harmony with form. One of the good examples of this principle is used in eggshell. It's structure is three dimensional form that transfer forces and tensions in pressure way. This principle is basic criteria in design of domes and thin shells in architecture. In the traditional Persian architecture, minimal use of material has always been of a great importance. This principal in modern architecture was revived by Van Der Rohe in an exaggerated way with the dictum "less is more"

and their Farnsworth House [fig11] demonstrates this view. This principle is most often observed in the works of some architects like Otto, Calatrava.



Figure 11: Van Der Rohe based on his dictum "less is more" use least material and light structure (Plano, Kendall County, Illinois, U.S. , 1945-51, Farnsworth House)

Using analogue models to find the form of a building in relation to the flow of forces, the geometries of scaled models should be transform. But in formal approach, mimicking is the best way to understanding and using functional and constructive aspects [Gruber, 2008:2].

Reaction to environmental influences: This principle is important topic in natural organisms. Reactions are usually towards sun, wind, Temperature, humidity and sounds in different ways. For example sunflowers return to sun pass in the sky to achieving maximum energy from sunshine rays [Fig12].in buildings reaction to environmental influences is planed and integrated into the it's design process. Building can be react through opening/closer control of access of living organisms, material or energy, movement of building parts, change or improvement of elements, space or internal environment [Gruber, 2008:5].using self- cleaning materials, remote roofs and surfaces or elements that can be adapt internal spaces and external surfaces with temperature, humidity, sunrays, sounds, desirable and undesirable winds and smells are actual ways for using of this principle in architecture. Intelligent buildings are good example for reaction to influences [fig13].



Figure 12: sunflowers reaction to sun by return to sunshine



Figure 13: Reaction to environmental influences in this project; integrates technology, multimedia, intelligent systems and user interactivity to create customizable living and working spaces that focus on experience (James Low, 2008-2010, Cybertecture Egg, Mumbai, India)

Hierarchy and self-similarity: Priority and hierarchical order in form and proportion are the manner to transfer force transfer and distinguish its course is important and determining principle. "There are many examples of such hierarchical structure in the forms we see in both nature and in made-made systems [fig14]. Energy in the form of blood, oxygen, and electric signals are delivered to the body through dendritic networks of arteries and veins, lungs, and nerves "[Batty, 2006, Mandelbrot,1967].In natural organisms, parts with joining each other make a complex, in the way that it has real unity. In nature's diversity, branches and leaves around the main axis of a plant are not by chance but in harmony with functional details and arrangement

[Fig15] every material based on its essential characteristics, is proper for a special task. With regard to the characteristics such as hardness, long life, resistant, flexibility, Nature defines the quality of each part. Moreover, form and function of parts slaps corresponding with their essence. The generation of order in architecture and living organisms is very different [Gruber, 2008:3]. Hierarchy in natural organisms is in some categories instance transfer of forces, joints of parts and elements, layering of materials based on softy or hardy of them, scale of parts and arrangement of parts. In architecture hierarchy cab be use in many ways instance hierarchy of access, transformation of forces and designing of structural parts, confidentiality of spaces, hierarchy in perception of spaces, rate of details based on scale of space and speedy of spectator, material selection, adjacent of spaces, junction of various scaled spaces, tonality of colors, establishment of spaces and mega-spaces in floors based on loads and numbers of users.

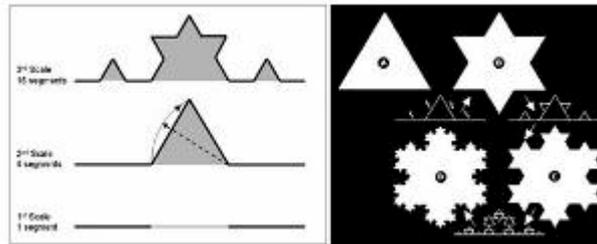


Figure 14: Constructing a Space-filling Curve: The Koch Snowflake Curve a)

Left: successive displacement of the central section of a line at ever fine scales b)

Right: application of the displacement rule to the lines defining a triangle shape called a Koch Island. This construction is a recursion of the same rule at different scales and it generates a pattern which is self-similar in that the motif – the triangular displacement occurs at every scale and is in a sense the hallmark of the entire construction (Batty, 1994, 2005, 2006).



Figure15: Resting stalk of leaves is not accidental rather indicate to a kind of geometrical pattern

Contiguity of parts: Parts define and control each other. In most cases, nature uses an intermediate part at the place of junction and as such these joints act in the best way as the hierarchy in living creatures. Junction of leaf to the stem of plant by petiolule is good example for this. In Persian architecture using of intermediate space is important principle [Fig16]. Since; organism's parts are complimentary to each other and thus should be in complete junction and fastened neatly. In other words, omitting any part damages the whole system. Wright and Sullivan have used the best manner in using and joining different scales to each other.



Figure 16: Use of intermediate space as natural patterns in traditional Persian architecture, Kashan Bazaar [Ardalan, and Bakhtiar, 2001:16]

Effective factors in organism formation: Gene is the main hidden factor, which is effective in the characteristics of shape and form, and this factor deals to sustainability of a natural creature. It is not just internal factors that affect the form or structure, but external factors too have vital role in forming any creature. In human dwellings, external factors contain framing and contents factors and body factors contains climate, materials, construction, and technology and containing factors contains culture, thought, religion and tradition. External factors cause variety and diversity because it is unnecessary that every part of an organism be of the same shape but every other detail regarding its characteristics and functions find its own geometry. Today, the corresponding effect of internal and external factors on the basis of the forms of living species proved sustainability towards nature and has had effect on the genes.

Multifunctional organism: Every part of a system doesn't have just one aim, rather have some secondary aims, in order to help other parts. As an example a part should help taking into account structural, functional, and aesthetic points of view [Scholer, 2005: 143]. Organism's parts besides structural role have some other responsibilities as well. For example, plants vessel, bird's feather have different functions. The "Big Eye" stadium in Japan, work of "Kisho Kurokawa", is as example of this kind of structure.

Internal connection of parts: A kind of inter-connection and flexibility in interior parts of organisms. In architecture, this is achieved just not by creating special forms, but through continuity and connection.

Evolution of abilities of the parts: unvalued parts would be efficient when they are put in a system, beside each other. As an example, we can name the use of reed in traditional architecture especially muddy architecture. Although reed is weak and unvalued outwardly but with a good structure and right joints, can strengthen the structure, or, using clay in clay and that leads to its high strength [Schloer, 2004: 226-323].

Variance of scales in organisms: There are different scales in nature and behaviors would shape on the basis of these scales. For example, the velocity of particle in very ting scales or very big ones is different. Also in the urban scale passages have hierarchical order based on the needed speed, and the house, which is the fix place, needs a kind of geometry symmetrical with tranquility and the high speed geometry of galaxies or atoms would connect and be helpful for it. We can make use of this important principle in architecture and the amount of details and ornaments related to the surface can be defined on the basis of the viewer's perception.

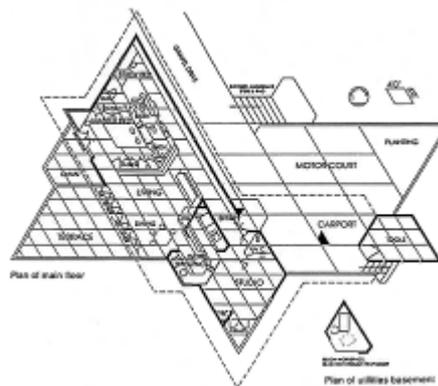


Figure 17: Wright also utilizing scales as well as joining different scales together has focused on natural organisms (The Frank Lloyd Wright House in Ebsworth Park, Missouri, 1943)

Capability of growth, change and permanent wholeness: The ability of growth and change, as a whole, are the characteristic of parts making every natural form. As an example, trees during million years of process have found unique method for encountering coldness and the seasonal change. They drop their leaves in winter and after passing severs cold and put on leaves again as soon as the environmental conditions are favorable. Capability of expansion in buildings that designed by Wright can be good samples for this principle [fig18].



Figure 18: with a rotunda in spiral forms expansion can be performance in this project (Wright, Guggenheim Museum, 1959, New York)

Flexibility: Fundamentally, most of nature's organisms have layers. In complex cases of them main structure is contain exterior sell and an inner tenacious structure that keepers parts. This structure has provided stability and flexibility. In cases that flexibility is not main factor for organism, merely by exterior sell both stability and flexibility are provided. This analogy can be used in architecture by designing on structure in simple building and multi- structure in complicated buildings.

Sustainability: In nature's organisms, every part is provided by nature and is being used in another shape after consumption and permutation. Nothing disappears in nature nor comes in to existence, but is always changing in shape and form [Jenkes, 2002:39]. Use of vernacular materials in architecture highlight this point however; the most contemporary architectural styles destroy nature by applying non- recyclable materials, and reparation of parts. Self- relief in natural orgasm is very important and interesting. When any parts of organisms are destroyed, rehabilitation of parts implement by existed materials. This principle can be used as resource of inspiration in rehabilitation of buildings and city.

Preservation of the identity of organism's parts: We should pay attention to the species and their typicality in architecture also. In this field and culture, self-consciousness is the most important individual factor and tradition is the most important social factor that refuses every unknown phenomenon, even though, in an imposed way.

Economy of nature: Geometry of organisms is on the basis of performance and coordination with their other parts as well as to respond the functional, economic and firmness circumstances. For example triangular grids are seen in nature repeatedly that is an organizing pattern. Examples of this architecture can be seen in Geodesic Dome [Fig21].

With a statistical look on the inventions and discoveries during the course of history, it's obvious that the models inspired from nature have been more economical, and more useful than the products arising from human endeavors and thoughts. As an example the system in Halophyte plants from the energetic efficiencies and maintenance expenses is much more economical than human made systems. In natural economy there is no sign of reducing the resources and devastation of environment alone but also malfunctioning and low profit resources and environments are repaired and can work as a productive and useful part. Branchy pattern in nature are one of the principles that recognizable in many living and nonliving organisms. There is however a much more literal morphology which is fractal and this is the shape of an object or set of linked objects that form a tree or dendrite [Fig19]. If you want to transport energy from some central source to many distant locations, it is more efficient to develop infrastructure that captures as much capacity for transfer as near to the source as is possible [Batty, 2005]. Inspiration from this morphology in Banquet Hall is used [fig20].

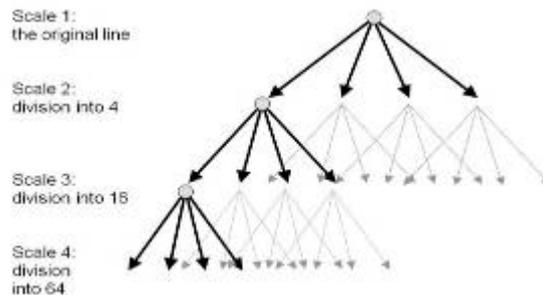


Figure 19: The Hierarchy of Composition in Constructing a Fractal (Batty, 1994, 2005, 2006)



Figure 20: Taking inspiration from the indigenous rain trees, the interior implements intricate “tree branch” wood paneling from the structure, spreading across the ceiling(Banquet Hall, Serie Architects, Mumbai, India,2009)



Figure 21: Use of soap bubbles form in architecture by "grimshaw" .soap bubbles are always connected in the form of irregular triangular grids. Triangular grids are the basis of the natural organism's geometry, which function on the minimum parts and maximum operation inspired from plants

5. Discussion and Conclusion

Architecture and its design is the process to choose the parts and reach to a unified wholeness. The basis to understand this phenomenon is deep insight on the architectural methods. In order to acquire a general outlook of architecture with a fixed aim, acquaintance of parts and their interrelations are necessary. Natural organisms that are the outcome of million years of gradual perfection, in a way give very instructive samples of such relationships between the parts are arise from the systematic essence of organisms. Inspiration from natural organisms can be useful in achieving an integrated and aimed architecture. The objective of such bodily and formal comparisons and inspirations are not the comparison between organism and architecture because different insight of this scale and inspiration encounter deficiency. The real aim is to identify natural characteristics and organism as well as rules and regulation governing on their structure. In better words, the aim is to accede systematic and organized compare to organisms, to increase the power to understand existing systematic structures, to acquire and extract principles and recreational tools of this order and other hidden values in it and to use these valuable perfect ions in architecture. The principle such as the manner to confront the natural forces, some of the characteristics include: selection of material, proper geometry, relation between parts, selection of the quality of the parts according to their necessary application, the way to join them together, the way to arrange in axis, hierarchical order of the system, differentiations in scales, forming factors and so forth, flexibility, reaction to environmental influences, harmonization between nature and sustainability. Encountering with natural systems, usually architects attempt to percept of proportions and form or aesthetical values but engineering try to understand and analysis ecstastic and dynamic rules, material resistance. Combination of these methods is useful way in biological architecture. Finally mention this point is important that comparison between building and whatever gradually occurs in nature is only part of design needs. Because buildings are regretful from widely political, social, humanistic and contextual needs besides structural and functional efficiency. By understanding rules of nature and using them, we can create high efficiency and proportional forms that we can named aesthetical structure. Whenever, aesthetic and efficiency assembles in structural forms that follow natural rules, we can claim that theses structures are same natural modeless.

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