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The Logic of Form Formation and Organization in Nature: A Framework for Developing Biomimetic Approaches in Architecture

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Abstract

Nature can be regarded as one of the richest sources for understanding the processes through which form is generated, transformed, and organized. Natural structures are not merely collections of visual forms; rather, they are the outcomes of complex processes of formation, growth, organization, and adaptation to the environment. Studying these processes can move beyond formal imitation and provide a basis for understanding the underlying logic governing the generation of form and spatial organization in architecture. In this context, geometric patterns, proportions, repetition, hierarchy, self-similarity, gradual growth, and the organization of natural structures are among the fundamental principles that significantly influence the formation and performance of natural systems. The present study aims to identify the logic of form formation and organization in nature and elucidate its potential for developing biomimetic approaches in architecture. The research adopts a review-analytical methodology, drawing on library research, specialized literature, and scientific articles on biomimetic architecture, natural geometry, and form-generation processes in nature. The findings indicate that focusing on the underlying logic of natural structures, rather than directly imitating natural forms, can contribute to the development of new approaches to architectural form generation and organization. Principles such as growth and transformation, repetition and variability, hierarchy, self-organization, geometric relationships, and adaptation to environmental conditions can serve as conceptual and methodological foundations for the architectural design process. Accordingly, nature can be considered not merely a source of visual inspiration, but also a source for understanding the logic of form generation and spatial organization. Applying such principles can strengthen the relationship between form, function, and environment and contribute to the development of architectural approaches that are more adaptive, dynamic, and responsive to human and environmental needs.

Keywords: Biomimetic architecture, Form formation logic, Form organization, Natural patterns, Natural geometry, Natural processes, Architectural design.

1 | Introduction

Since the earliest stages of human civilization, nature has consistently been one of the most important sources of inspiration in architecture and the design of living spaces. In their interaction with the natural environment,

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humans have not only learned methods of providing shelter and adapting to climatic conditions, but have also adopted fundamental principles such as order, proportion, balance, sustainability, and harmony from natural structures. Therefore, the relationship between nature and architecture cannot be reduced to mere visual imitation of natural forms; rather, it is grounded in an understanding of the deeper mechanisms that shape natural structures and patterns [1].

Throughout history, many prominent architectural works have been influenced by the observation and analysis of natural systems. Architects in different periods have sought to employ the proportions, patterns, and geometric relationships found in nature to create spaces that, in addition to possessing visual beauty, demonstrate structural coherence and functional efficiency. From the temples of ancient Greece and prominent examples of Persian-Islamic architecture to the works of contemporary architects, traces of inspiration from the principles governing nature can be observed [2].

With advances in the natural sciences and the development of computational technologies over the past few decades, the study of the relationship between nature and architecture has entered a new phase. Researchers have recognized that many natural structures are formed according to principles that can provide effective solutions to architectural and engineering challenges. This perspective has contributed to the emergence of approaches such as biomimicry and design based on natural systems. These approaches regard nature not only as a source of formal inspiration but also as a model for structural, functional, and environmental organization [3].

Among the various characteristics of nature, geometric order and symmetry hold a particularly significant position. Many natural phenomena follow precise organizational patterns and distinct geometric relationships that contribute to balance, harmony, and efficiency. These characteristics can be observed in plant structures, crystal arrangements, animal shells, growth patterns of living organisms, and numerous natural systems. The presence of such order has made nature one of the most important subjects of study for architects and designers, as many of these patterns can be translated into architectural design [4].

On the other hand, symmetry, as one of the most important manifestations of order in nature, plays a significant role in shaping human visual perception. Numerous studies have demonstrated that symmetrical structures, due to their balance and harmony, are generally perceived by humans as more beautiful, orderly, and comprehensible. Consequently, symmetry has become one of the fundamental principles of spatial and formal organization in architecture throughout history and has been employed in many significant architectural works worldwide [5], [6].

At the same time, developments in contemporary architecture indicate that the interpretation of order and symmetry has undergone considerable changes compared with the past. Although symmetry was predominantly employed explicitly and geometrically in classical architecture, contemporary approaches have increasingly incorporated concepts such as dynamic order, relative symmetry, complex geometry, and patterns derived from natural systems. This shift in perspective has heightened the importance of revisiting the concepts of order and symmetry in the contexts of nature and architecture. It has created opportunities for a deeper understanding of design processes [7].

From a theoretical perspective, many researchers have regarded order as a fundamental characteristic of both natural and artificial systems. Alexander argues that the life-enhancing quality of architectural spaces lies in the presence of organized patterns and coherent relationships among their constituent elements [2]. Salingaros likewise considers order to be a primary factor in establishing coherence within the built environment and suggests that successful architecture follows organizational principles similar to those observed in nature [8]. Ching, on the other hand, introduces geometry as the fundamental language of architecture through which spatial, structural, and perceptual relationships are established [9]. These perspectives demonstrate a profound relationship between natural order and the spatial organization of architecture, providing a foundation for the development of innovative design approaches.

Despite the growing body of research on biomimetic architecture, many existing studies have focused on the formal and aesthetic aspects of nature-inspired design. At the same time, comparatively less attention has been devoted to systematically examining the role of geometric order and symmetry as fundamental principles in architectural thought. Consequently, there remains a need for research that examines these concepts and their influence on architecture in an integrated manner.

Accordingly, the present study adopts a review-analytical approach to investigate the role of geometric order and symmetry in nature and their influence on architecture. The primary objective of this article is to establish the theoretical foundations of these concepts, analyze their manifestations in natural structures, and examine how they are reflected in architectural works. To this end, the study first examines the concept of order in nature and the principles governing it, followed by an analysis of the role of symmetry in natural structures and architecture. Finally, the potential of these patterns to inform contemporary architectural design approaches is evaluated.

2 | Research Methodology

The present study adopts a review-analytical approach and aims to investigate the role of geometric order and symmetry in nature and their influence on architecture. The research draws on library research and qualitative content analysis to elucidate the relationship between natural patterns and architectural design principles through a systematic examination of scholarly sources.

In the first stage, relevant scientific literature was collected from reputable international and domestic databases. The selected sources included specialized books, research articles, peer-reviewed publications, and studies on architecture, natural geometry, biomimicry, order, symmetry, and nature-based design. The literature search was conducted using a set of keywords related to the research topic, including "nature-inspired architecture," "biomimicry in architecture," "order in architecture," "symmetry in architecture," "natural geometry," "geometric patterns," and "fractal geometry." These keywords were used both individually and in various combinations to ensure comprehensive coverage of relevant studies.

Following the literature review, a screening process was conducted based on thematic relevance, academic credibility, citation impact, and publication status. Sources that directly addressed the concepts of geometric order, symmetry, natural structures, and their applications in architecture were selected, while less relevant sources were excluded. An effort was also made to incorporate a balanced mix of classical theoretical works and contemporary research to provide a comprehensive understanding of the development of theories on the subject.

In the next stage, the extracted data were examined using qualitative content analysis. To this end, recurring concepts and themes identified across the reviewed sources were categorized into four principal dimensions: "order in nature," "symmetry in nature," "symmetry in architecture," and "natural geometry and geometric patterns in architecture." Subsequently, through comparative analysis, the relationships among these concepts and their influence on the development of architectural ideas and design strategies were evaluated.

Finally, the findings from the literature analysis were organized into a coherent theoretical framework to facilitate interpretation of the role of natural patterns in the formation of spatial order, architectural structures, and contemporary design approaches. This framework provides the basis for further analysis and discussion of the position and significance of geometric order and symmetry in contemporary architecture.

3 | Theoretical Foundations

3.1 | Order in Nature

Order is one of the fundamental characteristics of the natural world and can be observed at virtually every level of existence, from microscopic structures to large-scale cosmic systems. Although nature may initially appear to be a collection of diverse, sometimes random phenomena, scientific investigations reveal that underlying this apparent diversity is a complex system of geometric relationships, recurring patterns, and organizing principles that contribute to the formation of stable, efficient structures. In this sense, order in nature represents a form of organization through which the different components of a system are placed in coordinated and purposeful relationships with one another [6].

From a scientific perspective, order is the presence of recognizable patterns in the structure or behavior of a system. These patterns often emerge from interactions among physical, chemical, and biological laws, enabling natural systems to achieve high levels of efficiency with relatively low energy and material consumption. This characteristic has made nature not only a subject of study across various scientific disciplines but also a valuable model for architecture, design, and engineering [9].

Ball [4], in his three-volume work, Nature's Patterns, explains that many natural forms and structures are the outcomes of organized processes influenced by the fundamental forces of nature. From his perspective, despite its remarkable diversity, nature follows a relatively limited set of laws and geometric patterns. These principles contribute to the formation of various structures, including crystals, cellular networks, plant structures, animal shells, fluid flows, and even large-scale natural systems. According to Ball [4], studying these patterns can provide a deeper understanding of the mechanisms governing nature and facilitate their translation into design practice.

One of the most important manifestations of order in nature is the emergence of geometric patterns. Geometry can be regarded as a common language shared by nature and architecture—a language that describes relationships among components, proportions, and the organization of structures. Numerous natural phenomena follow specific geometric principles. The hexagonal structure of honeycombs, crystalline networks, spiral patterns in shells, and the arrangement of leaves along plant stems are examples of geometry in nature. These patterns are not merely aesthetic phenomena; rather, they emerge from processes that operate to achieve greater efficiency and minimize energy expenditure [4].

Among natural structures, cellular networks represent a prominent example of geometric order. Plant cells, soap-film structures, cracks formed by soil desiccation, and numerous geological formations exhibit similar organizational patterns. These structures demonstrate how nature can generate complex and stable systems through the repetition and organization of relatively simple units. Research in natural geometry has shown that such patterns can serve as a basis for the design of architectural envelopes, lightweight structures, and spatial frameworks [4].

Another key concept in the study of natural order is self-organization. Self-organization refers to a process by which order emerges without the intervention of a central controller, solely through interactions among the components of a system. Many natural structures and phenomena follow this principle. The formation of ant colonies, collective behavior of birds, crystal growth, and cellular organization are examples of self-organizing processes. These phenomena demonstrate that order in nature often emerges from the bottom up and results from continuous interactions among the elements of a system [10].

Studies by Pearce [11] suggest that natural structures can be regarded as optimized and intelligent systems that have evolved over millions of years. In his book, Structure in Nature Is a Strategy for Design, he argues that nature continuously seeks solutions that achieve maximum structural strength with minimal material consumption. Consequently, many natural structures exhibit characteristics such as lightness, flexibility, efficient force distribution, and high stability. From Pearce's [11] perspective, these characteristics can serve as effective strategies for architectural and structural design.

One of the best-known examples of this approach is the honeycomb's hexagonal structure. By using a minimum amount of wax, the honeycomb provides substantial storage capacity and structural strength. This characteristic has made the hexagonal pattern one of the most important geometric forms employed in architecture, industrial design, and structural engineering. Many contemporary lightweight envelopes and spatial structures have been inspired by this geometric logic [11].

In addition to cellular structures, nature also makes extensive use of fractal patterns. Fractals are structures that exhibit similar characteristics across different scales. Tree branches, plant venation, river networks, coastlines, and the structure of the human lungs are examples of fractal geometry in nature. These structures facilitate the efficient distribution of energy, materials, and information while simultaneously exhibiting considerable visual complexity and aesthetic quality [12].

Furthermore, many natural forms are based on mathematical relationships and geometric proportions. The golden ratio, Fibonacci sequence, and spiral patterns are among the concepts frequently associated with natural structures. The arrangement of sunflower seeds, the shells of certain marine organisms, plant growth patterns, and even some patterns observed in galaxies have been cited as examples of mathematical order in nature. Researchers have interpreted these relationships as manifestations of the harmony between natural growth processes and geometric principles [13].

Natural order is not limited to shape and form; it also plays a fundamental role in the functioning of natural systems. The circulatory, respiratory, skeletal, and spatial organization of plants all demonstrate how nature achieves high levels of efficiency through the precise organization of its components. This principle is particularly significant in sustainable architecture, as one of the primary objectives of sustainable design is to achieve maximum performance while minimizing resource consumption. Therefore, studying natural order can provide a valuable foundation for developing innovative design approaches and optimizing building performance [3].

An examination of contemporary architectural works demonstrates that many architects, inspired by the order found in nature, have sought to incorporate natural organizational principles into their designs. Within this approach, nature is considered not merely a source of formal inspiration, but also a model for understanding structural relationships, spatial organization, and environmental performance. This perspective has contributed to the development of approaches such as biomimetic architecture, biophilic design, and sustainable architecture, which are now regarded as significant intellectual currents in contemporary architectural thought [1], [14].

Overall, order in nature can be understood as the outcome of the interaction among geometry, physical laws, growth processes, and evolutionary mechanisms. This order not only contributes to the formation of aesthetically coherent structures but also enables stability, efficiency, and balance. Understanding these principles can open new horizons for architects and facilitate the application of natural strategies in architectural design. In this context, one of the most significant manifestations of natural order is the concept of symmetry, which will be examined in detail in the following section.

3.2 | Symmetry in Nature

Weyl [5], in his book Symmetry, introduces symmetry as one of the fundamental principles governing the organization of the natural world and describes it as a bridge between beauty, mathematics, and structure. From his perspective, symmetry is not merely a geometric property but rather a reflection of the underlying order of natural systems. This perspective has made symmetry a key concept in the study of natural forms and the analysis of architectural structures.

From a scientific perspective, symmetry refers to a form of order and harmony in the arrangement of a system's components, contributing to structural balance, stability, and efficiency. Throughout the evolutionary process, nature has continually developed patterns that, while visually coherent and aesthetically pleasing, are also functionally efficient. Consequently, the study of symmetry has gained considerable significance not only in biology and physics but also in architecture and design [4].

Ball [4], in his three-volume work, Nature’s Patterns, explains that many patterns found in nature result from interactions among physical forces, geometric principles, and growth processes. From his perspective, natural forms and patterns are not merely decorative phenomena; rather, they are the outcomes of complex mechanisms that operate to achieve greater efficiency and minimize energy consumption. Crystal structures, the cellular organization of plants, mineral networks, and even the growth patterns of animals all follow specific geometric principles and symmetries [4].

One of the most common forms of symmetry in nature is bilateral symmetry, which is evident in the bodies of many living organisms. Humans, birds, mammals, and numerous insects possess an axis of symmetry that divides their bodies into two approximately similar halves. This form of organization contributes to the balanced distribution of forces, facilitates movement, and enhances functional efficiency. In contrast, radial symmetry, observed in flowers, corals, and certain marine organisms, enables balanced interaction with the surrounding environment.

Among the various manifestations of natural order, crystalline structures hold a particularly significant position. Crystals form through the regular repetition of molecular units, resulting in geometric and symmetrical networks. Snowflakes are a well-known example of this phenomenon. Despite their remarkable diversity in form, snowflakes generally follow a fundamental hexagonal structure. This geometric order results directly from the molecular arrangement of water and the physical laws governing the crystallization process [4].

Pearce describes nature as a collection of intelligent structural systems that have evolved over millions of years. In his view, natural structures are valuable not only for their aesthetic appeal but also for their effective solutions to structural challenges. The hexagonal patterns of honeycombs, skeletal networks of marine organisms, and crystalline structures demonstrate how nature consistently seeks to achieve maximum strength with minimum material consumption [11].

According to Pearce [11], many natural systems are based on space-frame geometries and three-dimensional networks, in which symmetry plays a fundamental role. Due to their efficient force distribution, high stability, and optimized material use, these structures can serve as valuable models for architectural and engineering design. Therefore, studying symmetry and geometric order in nature is not limited to understanding natural beauty; it can also serve as a means to understand design principles and create efficient, sustainable spaces.

Overall, symmetry can be regarded as a shared language between nature and architecture. Through the use of symmetrical patterns and organized geometric structures, natural systems have achieved balance, strength, and efficiency simultaneously. Understanding these patterns provides architects with a valuable source of inspiration and can contribute significantly to the development of innovative design approaches, particularly in biomimetic and sustainable architecture.

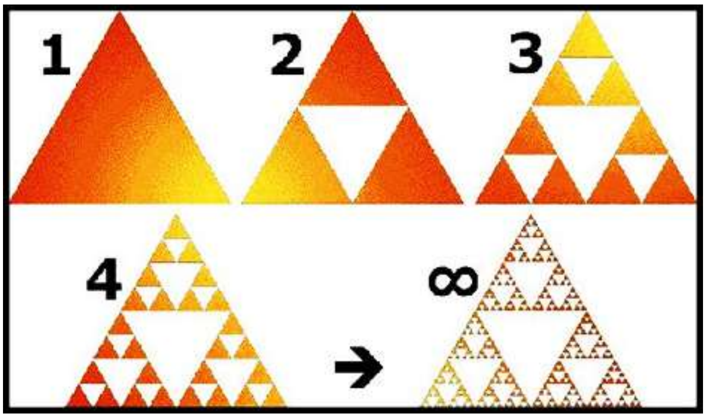


Fig. 1. The Sierpiński triangle as an example of rotational symmetry and self-similarity [12].

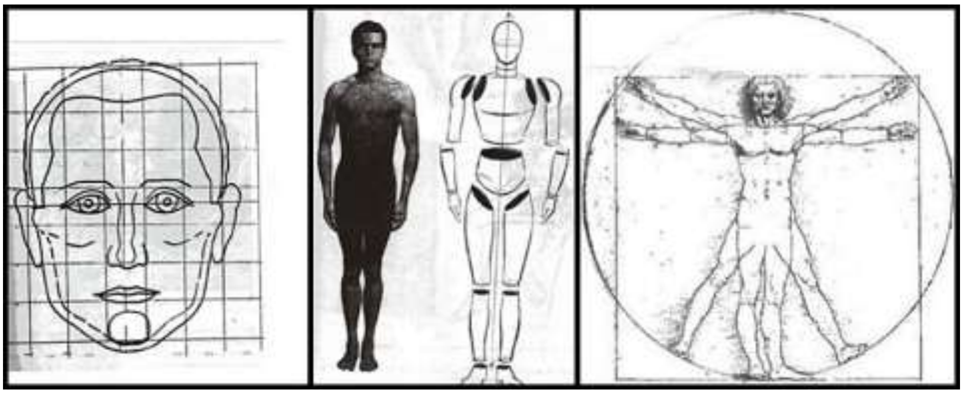


Fig. 2. An example of bilateral symmetry in the human body [5].

3.3 | Symmetry in Architectural Formation

Symmetry is considered one of the oldest and most influential principles of spatial organization in the history of architecture. From the earliest monumental structures to the most complex works of contemporary architecture, symmetry has consistently been employed to establish order, balance, coherence, and spatial legibility. Since ancient times, humans have associated symmetrical structures with concepts such as harmony, stability, strength, and beauty. This association has contributed to the establishment of symmetry as a fundamental principle of architectural design [9].

Studies in environmental perception indicate that the human mind naturally processes and comprehends symmetrical structures more rapidly. This characteristic allows symmetrical spaces to achieve greater visual clarity and enhances users' perception of order and tranquility. Consequently, throughout history, architects have employed symmetry not only as an aesthetic device but also as a means of organizing space and guiding users' perception and experience of architectural environments [15].

Fig. 3. Manifestation of axial symmetry and geometric order in the Taj Mahal complex [16].

One of the earliest examples of the deliberate use of symmetry can be observed in the architecture of ancient civilizations. In ancient Egyptian architecture, symmetry was employed as a symbol of power, cosmic order, and political authority. The principal axes of temples, tombs, and ceremonial complexes were organized symmetrically to convey a sense of grandeur and magnificence to the viewer [17].

In ancient Greek architecture, symmetry also held a particularly significant position. The Greeks believed that beauty emerged from harmony among architectural elements and adherence to precise proportions. Consequently, many Greek temples, including the Parthenon, were designed according to symmetrical relationships and proportional systems. In these works, symmetry is evident not only in the plan's organization but also in the design of façades, columns, and architectural elements [18].

Ancient Roman architecture, influenced by Greek principles, also made extensive use of symmetry. Vitruvius, in his treatise The Ten Books on Architecture, identifies symmetry as one of the fundamental principles of architectural design and considers it an essential factor in achieving harmony among a building's components [19].

In Persian architecture, symmetry holds a position that extends beyond a purely geometric principle and is closely associated with cultural, philosophical, and symbolic concepts. Many historic buildings in Iran were designed around axes of symmetry, with their spatial organization expressing internal order and harmony among their constituent elements. This characteristic can be observed in Persian gardens, mosques, schools, and historic palaces [14].

In Islamic architecture, symmetry is often associated with concepts of unity, perfection, and divine order. The organization of central courtyards, iwans, domes, and prayer halls in many Islamic buildings is based on symmetrical relationships. The Jameh Mosque of Isfahan, Sheikh Lotfollah Mosque, and Imam Mosque are among the prominent examples of symmetry in Iranian Islamic architecture [20].

One of the important characteristics of Islamic architecture is the integration of symmetry with complex geometry. In this architectural tradition, symmetry is often combined with repetitive patterns, geometric proportions, and ornamental grids to create coherent, harmonious structures. This approach has enabled symmetry to function not only as a means of spatial and formal organization but also as an important element in conveying cultural, symbolic, and philosophical meanings [21].

Fig. 4. An example of translational symmetry and geometric repetition in the tilework of Sheikh Lotfollah Mosque, Isfahan [21].

With the emergence of the Modern movement in the twentieth century, architects' attitudes toward symmetry underwent significant transformation. Many modern architects sought to move away from the rigid patterns of classical symmetry and organize space according to function, flexibility, and emerging architectural requirements. Nevertheless, symmetry was never completely abandoned and has persisted in various forms throughout contemporary architecture [21].

Architects such as Corbusier [22] employed proportional systems inspired by nature to establish balance in architectural design. The Modulor system, developed by Corbusier [22], aims to establish a relationship among human proportions, geometry, and architecture.

In recent decades, with the advancement of digital technologies and the development of parametric design, the concept of symmetry has undergone further transformation. In many contemporary projects, rather than relying on complete and explicit symmetry, architects employ concepts such as dynamic symmetry, relative symmetry, and geometric balance. The works of architects such as Santiago Calatrava, Norman Foster, and Zaha Hadid demonstrate how principles of natural order and symmetry can be incorporated into complex and innovative architectural forms [7].

3.4 | Symmetry in Perception and Spatial Quality

Beyond its historical and formal dimensions, symmetry plays an important role in spatial perception. Studies in environmental psychology have shown that symmetrical spaces are generally perceived as more comprehensible, legible, and orderly. The presence of clear axes, balanced distribution of elements, and harmony among components can enhance users' feelings of calmness, security, and spatial coherence [15].

However, excessive reliance on symmetry may lead to monotony and diminish spatial dynamism. For this reason, many contemporary architects seek to establish a balance between order and diversity, symmetry and asymmetry, and stability and dynamism. This perspective has transformed symmetry from a purely geometric principle into a tool for shaping and managing users' spatial experiences [9].

Historical and theoretical examinations of symmetry in architecture demonstrate that it has consistently been one of the most important tools for organizing space and form. Although how symmetry has been employed has changed across different periods, its role in establishing order, balance, legibility, and spatial quality has remained significant. From ancient architecture to contemporary practice, symmetry has served as a bridge between aesthetics, function, and meaning, remaining one of the fundamental principles of architectural design.

Although symmetry is regarded as one of the principal means of establishing order in architecture, achieving desirable spatial quality does not necessarily require complete symmetry. The concept of balance refers to the ability of the elements within a composition to establish visual stability and overall harmony, even in the absence of complete symmetry. From this perspective, balance is a broader concept than symmetry and depends on the distribution of spatial elements, volumes, colors, and visual weight within a composition [15].

Arnheim considers balance one of the most important principles of visual perception and argues that the human mind continually seeks to establish balanced relationships among the components of a composition. In contemporary architecture, many buildings have achieved balance through the careful organization of spatial elements despite lacking geometric symmetry. Therefore, symmetry and balance can be understood as complementary concepts that work together to establish order, legibility, and spatial quality in architecture [15].

4 | Natural Geometry, Symmetry, and Architectural Patterns

Geometry can be regarded as one of the most important common languages shared by nature and architecture. Many natural structures are formed according to specific geometric relationships, which contribute to their order, balance, efficiency, and aesthetic qualities. Architects have likewise sought, throughout history, to understand these patterns and translate them into the built environment, creating spaces that are harmonious, sustainable, and efficient. In this sense, geometry is not merely a tool for organizing form and space but also a means of gaining a deeper understanding of the relationship between nature and architecture [9].

Ball [2] considers many natural forms to be the outcomes of geometric processes shaped by physical and biological laws. According to his perspective, the patterns found in nature are not merely aesthetic phenomena; rather, they reflect nature's underlying logic for achieving stability, efficiency, and organization. This characteristic has made natural geometry one of the most significant sources of inspiration for contemporary architecture.

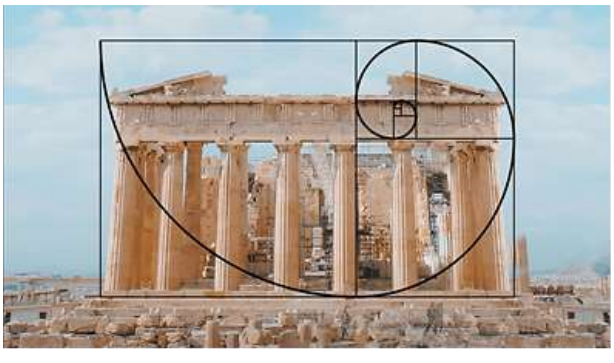
4.1 | Proportion and Geometric Ratios in Nature

4.1.1 | The golden ratio and natural proportions

One of the most well-known geometric relationships found in nature is the Golden Ratio, with a value of approximately 1.618. This ratio has been observed in various natural structures, including shell forms, ram-horn growth patterns, and certain patterns of plant development. Researchers have suggested that the Golden Ratio can contribute to a form of visual balance that humans perceive as harmonious and aesthetically pleasing [13].

The influence of this ratio on architecture can be traced from antiquity to the present day. Numerous historical buildings, ranging from ancient Greek temples to certain Renaissance works, have been associated with proportions approximating the Golden Ratio. In contemporary architecture, the Golden Ratio continues to be used as a design tool to establish proportion, balance, and spatial harmony [23].

Fig. 5. The Golden Ratio and logarithmic spiral in the structure of a nautilus shell [13].



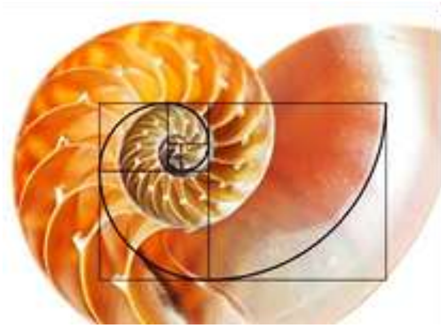


Fig. 6. Application of the Golden Ratio in the geometric organization of the Parthenon façade [23].

4.1.2 | Fibonacci sequence and growth patterns

The Fibonacci sequence is another significant mathematical pattern found in nature. In this sequence, each number is obtained by adding the two preceding numbers, and the resulting ratios progressively approach the Golden Ratio. Various natural structures, including the arrangement of sunflower seeds, pinecones, pineapples, and the phyllotactic patterns of certain plants, exhibit Fibonacci-like patterns [13].

The significance of the Fibonacci sequence in architecture lies primarily in its relationship to growth processes and structural organization. Some architects have incorporated Fibonacci-based patterns into the design of forms, spatial organization, and architectural proportions to establish a sense of natural harmony and coherence among a building's components [24].

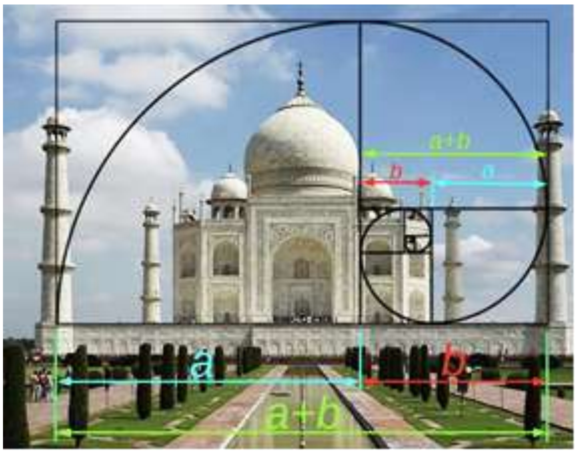


Fig. 7. The spiral pattern of Aloe polyphylla as an example of geometric order in nature [4].

Fig. 8. Application of geometric proportions in the design of Sheikh Lotfollah Mosque, Isfahan [21].

4.1.3 | Hexagonal structures and optimized networks

One of the most efficient geometric forms found in nature is the hexagonal structure. The honeycomb is a well-known example of this pattern, providing maximum spatial storage capacity with minimal material consumption. Pearce considers this structure an example of natural optimization that can serve as a valuable model for architectural and structural design [11].

Hexagonal networks are widely used in contemporary structural applications due to their efficient force distribution, light weight, and high strength. Geodesic domes, space-frame structures, and certain lightweight structural systems are examples of this pattern in architecture [11].

4.1.4 | Crystalline structures and geometric order

One of the most prominent manifestations of order in nature can be observed in crystalline structures. Crystals form through the regular, repetitive arrangement of atoms and molecules according to specific geometric principles. These structures represent examples of nature's inherent order, emerging without direct external intervention and primarily through physical and chemical laws.

Crystalline patterns can be observed in minerals, rocks, and even certain biological structures, demonstrating the profound relationship between geometry and natural processes. Ball [4] argues that crystalline structures are among the clearest examples of order emerging from apparent disorder, whereby individual particles, by following relatively simple rules, generate complex and highly organized structures.

The symmetries found in many crystals, including axial and rotational symmetry, demonstrate the fundamental role of geometry in the organization of natural systems. Therefore, studying crystalline structures can provide architects with a deeper understanding of the concepts of order, symmetry, and spatial organization, while also creating opportunities to draw inspiration from natural processes in architectural design [4].

Fig. 9. A crystalline structure as an example of geometric order in nature [4].

Fig. 10. The Royal Ontario Museum; an example of the reinterpretation of crystalline geometry in contemporary architecture [25].

4.1.5 | Fractal geometry in architecture

One of the most significant developments in twentieth-century geometry was the concept of fractals. Fractals are structures that exhibit similar characteristics across different scales. This property, known as self-similarity, can be observed in numerous natural phenomena, including tree branches, river systems, lung structure, and various biological networks [12].

Studies have demonstrated that many historical and contemporary architectural works exhibit fractal characteristics. In Islamic architecture, examples of fractal organization can also be identified in geometric patterns, muqarnas, and ornamental structures. The application of fractal geometry in architecture can not only generate visual complexity but also enhance spatial legibility and perceptual attractiveness [8].

Fractal characteristics can be observed in the branching structures of trees, coastlines, clouds, and numerous other natural systems. Subsequent research has indicated that incorporating fractal principles into architectural design can contribute to organized complexity, visual richness, and enhanced perceptual quality of architectural spaces [24].

5 | Findings and Discussion

A review of the literature and existing studies indicates a deep, multilayered relationship between natural structures and the principles of architectural organization. This relationship is not limited to visual similarities between natural and architectural forms; rather, it often involves the transfer of geometric logic, structural systems, and spatial organizational patterns from nature into architecture. The findings of the present study demonstrate that geometric order and symmetry are among the most important factors establishing this relationship between nature and architecture and have played a significant role in the development of architectural ideas and design strategies throughout history.

One of the most significant findings is the presence of geometric order as a fundamental principle shared by nature and architecture. Previous studies indicate that many natural structures follow specific geometric relationships that contribute to balance, harmony, and stability [4]. Such order can be observed in cellular structures, plant growth patterns, crystalline networks, branching systems, and numerous other natural phenomena. In architecture, geometry has likewise long served as a means of organizing space, defining relationships among elements, and establishing spatial coherence. Historical architectural works demonstrate that, from antiquity onward, architects have employed geometric grids and mathematical proportions to achieve balance and harmony. This principle can be observed in classical architecture, Iranian-Islamic architecture, and contemporary architectural practice. The findings indicate that geometry should not be regarded merely as a graphic or representational tool, but rather as a conceptual system for organizing the built environment.

Furthermore, comparing natural structures and architecture demonstrates that many geometric principles found in nature have considerable potential for application in architectural design. The Golden Ratio, branching patterns, crystalline structures, and hexagonal networks are examples of such principles that have influenced the development of architectural forms and structural systems [11]. These findings are consistent with Padovan's [23] perspective, which argues that geometric proportions serve not only as tools for generating aesthetic quality but also play an important role in establishing structural coherence and spatial legibility. From this perspective, geometry can be understood as a common framework for interpreting the relationships between nature and architecture.

The analysis of the literature further demonstrates that symmetry is one of the principal means of establishing order in architecture. Although the way symmetry has been employed has changed across historical periods, its role in enhancing spatial legibility, visual balance, and formal coherence has remained significant. Studies in environmental psychology indicate that humans tend to perceive symmetrical structures more rapidly and evaluate them as more orderly and predictable [15].

In traditional architecture, symmetry was primarily used to establish order and emphasize the principal axes of space. Numerous historical buildings in Iran, including Persian gardens, mosques, and governmental complexes, demonstrate the application of symmetry in spatial organization [14]. In such works, symmetry not only establishes visual balance but also significantly guides movement and defines spatial hierarchy.

In contrast, contemporary architecture offers a more flexible interpretation of symmetry. In many recent projects, complete symmetry has been replaced by dynamic balance and complex geometric relationships. This transformation demonstrates that the fundamental principle of order has been retained, while its mode of expression has evolved in response to new technologies and contemporary requirements [7]. The findings indicate that the concept of symmetry in contemporary architecture has extended beyond its classical definition. This observation is consistent with Weyl's [5] perspective on symmetry as a dynamic principle associated with the organization of structures. Consequently, what is important in contemporary architecture is not necessarily the precise repetition of elements around an axis, but rather the preservation of balance, coherence, and spatial organization.

Another significant finding concerns the relationship between natural structures and architectural structural optimization. Over millions of years of evolution, nature has developed structures capable of achieving maximum strength and efficiency with minimal material consumption. The honeycomb, cellular networks, branching patterns, and skeletal structures of living organisms are examples of such optimization strategies [11].

Studies indicate that numerous contemporary architects and engineers have drawn upon these patterns to develop lightweight, strong, and sustainable structural systems. Geodesic domes, space-frame structures, and lattice shells are among the examples in which nature's structural logic has directly influenced design. In such cases, nature serves not merely as a source of formal inspiration but as a model for addressing structural and functional challenges. This finding suggests that studying natural structures can contribute to the development of innovative structural solutions and to reducing material consumption, thereby playing an important role in enhancing architectural sustainability.

Finally, the literature review indicates that advances in digital technologies have played a significant role in expanding the field of nature-inspired architecture. The development of parametric design software, algorithmic modeling, and simulation tools has enabled the study and reproduction of complex natural patterns [26]. In this approach, the objective is not simply to imitate natural forms but to reproduce the logic of form generation, organization, and structural behavior observed in natural systems. Numerous contemporary projects have employed algorithms inspired by natural growth processes to generate forms that may offer greater structural and functional efficiency than conventional approaches. Research in biomimetic architecture demonstrates that nature can serve as a knowledge system, providing architects with strategies for addressing complex design problems. From this perspective, nature is not only a source of form generation but also a model for developing innovative design methodologies [3].

The direct relationship between natural order and sustainability in architecture may represent one of the most important prospects for future research in this field. As demonstrated, many natural structures are based on principles of optimization and can achieve high performance with minimal energy and resource consumption [4]. These characteristics can provide valuable models for the development of sustainable architecture.

However, the literature also indicates that not every nature-inspired project necessarily results in sustainable architecture. Some examples focus primarily on the superficial imitation of natural forms without incorporating their underlying functional logic. In such cases, nature is reduced to a decorative element. In contrast, the most successful projects are those that transform the structural, functional, and environmental principles of natural systems into architectural strategies [1].

Therefore, the future of nature-inspired architecture depends on moving beyond formal imitation toward a deeper understanding of natural systems. Such an approach can contribute to the development of architecture that is more sustainable, efficient, and environmentally responsive.

Overall, the relationship between nature and architecture can be conceptualized through a three-level conceptual model. At the first level are natural patterns, including geometric order, symmetry, branching structures, cellular networks, fractals, and crystalline structures. At the second level are the principles extracted from these patterns, including balance, coherence, organization, optimization, sustainability, and structural efficiency. Finally, at the third level, these principles are translated into architectural strategies, including spatial organization, structural design, form generation, parametric architecture, biomimetic architecture, and sustainable design.

This model demonstrates that the transfer of knowledge from nature to architecture does not occur through direct imitation of natural forms. Rather, it requires extracting fundamental principles and translating them into design strategies. Accordingly, a deeper understanding of natural mechanisms can play a significant role in advancing innovative approaches to architectural design.

6 | Conclusion

The present study demonstrates that the relationship between nature and architecture cannot be explained solely through visual similarities; rather, it is grounded in deeper principles such as order, symmetry, proportion, and organization. Within this framework, geometric order emerges as one of the most significant links between natural structures and architectural thought. This relationship can be observed in diverse patterns, including crystalline structures, fractals, branching systems, and geometric ratios found in nature.

From an architectural perspective, symmetry remains one of the most effective tools for establishing legibility, coherence, and spatial order. Nevertheless, in contemporary architecture, an exclusive emphasis on formal symmetry has increasingly given way to broader concepts such as balance, equilibrium, and spatial coherence.

Accordingly, the value of nature-inspired architecture lies not in the direct imitation of natural forms, but in understanding the underlying logic, organizational mechanisms, and latent principles that govern them.

From this perspective, nature should be regarded not merely as a formal model but also as a source of knowledge and a generator of design principles that can fundamentally contribute to aesthetic quality, structural performance, spatial efficiency, and environmental sustainability in architecture.

Therefore, the future of nature-inspired architecture depends on a deeper understanding of natural mechanisms and their intelligent integration into the design process. Such an approach can move architecture beyond superficial imitation toward creative interpretation, informed innovation, and meaningful design, establishing a more productive relationship between natural systems and the built environment.

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All aspects of the research and manuscript preparation were carried out by the author. The author has read and approved the final version of the manuscript.

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This article does not contain any studies with human participants performed by the author.

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