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Learning from Nature: Biomimicry as a Framework for Socially Integrative Urban Architecture

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Abstract: The accelerating interaction between nature, technology, and architecture has transformed biomimicry into a critical framework for designing socially integrative urban spaces. This study investigates how the combination of biomimicry and parametric design can generate architectural forms that promote both ecological sustainability and social inclusivity. The main aim is to develop a methodological approach—termed parametric biomimicry—that utilizes computational tools to translate the logic of natural systems into urban architectural design. Employing a qualitative research methodology supported by digital modelling experiments, the study integrates biomimetic principles with parametric algorithms through Rhinoceros–Grasshopper software. The "Snail Pavilion" was selected as a case study due to its spiral morphology, symbolizing continuity, protection, and adaptability in nature. The design process demonstrates how geometric parameters derived from biological systems can be algorithmically transformed into flexible and socially engaging spatial configurations. Findings reveal that the parametric-biomimetic approach not only improves environmental performance—reducing material waste by 18% in digital simulations—but also enhances social interaction through inclusive spatial gradients. The study concludes that biomimicry, when combined with computational design, transcends aesthetic imitation to serve as a model for social integration in urban architecture. This research contributes to the architectural literature by proposing a contemporary paradigm where digital biomimicry operates as a bridge between ecological intelligence and human-centered design.

Keywords: Biomimicry, Parametric Design, Urban Architecture, Social Integration, Computational Design

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I. Introduction

Architecture has always evolved as an interdisciplinary field shaped by the dynamic relationship between nature, technology, and humanity. Throughout history, natural forms, systems, and cycles have inspired human-built environments. However, in the 21st century, with the advancement of digital technologies and computational design tools, the process of learning from nature has shifted from mere imitation to data-driven, algorithmic reinterpretation (Zari, 2023; Dündar, 2019).

Within this context, biomimicry has emerged as an innovative design philosophy that analyses living systems and translates their organizational logic into sustainable architectural strategies. Biomimicry is a relatively new term, but its connotations have been part of architecture for thousands of years, especially in the creation of form and imitation of structural systems. Throughout history, nature's systems, models and cycles have always been used in the search for new forms and concepts. This approach is interested in how we can adapt nature to our systems and designs. As new methods have emerged in every field with the development of technology, the biomimicry approach has brought new methods with it. Creative methods and innovative techniques that affect the design process of design-oriented departments such as architecture are constantly developing with technology (Amer, 2009). Defined by Benyus (1997) as "innovation inspired by nature," biomimicry has gained new relevance in recent years—not only for ecological performance but also for its potential to reframe the relationship between people and the natural environment. Despite this growing interest, a clear gap remains in the architectural literature: most biomimetic studies focus on environmental optimization, façade morphology, or material efficiency, while the social dimension of biomimicry—particularly its role in fostering social integration within urban public spaces—remains underexplored.

This research addresses that gap by introducing a new methodological synthesis termed parametric biomimicry, which integrates nature-inspired systems with computational design processes. The primary objective is to explore how natural principles can be algorithmically transformed into socially inclusive and ecologically efficient urban forms using parametric tools such as Rhinoceros–Grasshopper.

The chosen case study, the Snail Pavilion, embodies this integration. The spiral morphology of the snail shell represents continuity, adaptability, and protection—qualities that naturally align with the objectives of socially integrative urban design. Its spatial organization, characterized by a gradual transition from exterior openness to interior enclosure, serves as a biomimetic metaphor for social inclusion and collective coexistence. Thus, the snail was selected not only for its structural efficiency but also for its symbolic and experiential relevance to urban sociality.

Research Questions:
-How can biomimicry contribute to strengthening social interaction in urban public spaces?
-How can parametric tools facilitate the translation of natural systems into architectural design?
-What are the spatial and social outcomes of integrating biomimicry and parametric design?
Hypothesis:
The integration of biomimetic principles with parametric design tools enables the transformation of natural forms and systems into urban spaces that are both ecologically efficient and socially inclusive. The Snail Pavilion model demonstrates that digital biomimicry can function as a bridge between human interaction and nature-inspired spatial generation.
In summary, this study aims not only to examine the technical convergence of biomimicry and parametric design but also to extend their combined application toward socially responsible architectural practice. By reinterpreting nature's logic through digital methods, the research contributes to the evolving discourse on how computational design can enhance social sustainability and biophilic engagement in urban environments.

Objectives and Scope

The primary aim of this study is to investigate how biomimicry, when integrated with parametric design tools, can be employed to generate architectural forms that simultaneously promote ecological sustainability and social integration in urban contexts. The research seeks to develop a methodological framework—defined as parametric biomimicry—that utilizes algorithmic modelling to translate the organizational logic of natural systems into adaptable urban architectural solutions.

The study specifically focuses on the Snail Pavilion, a design experiment that embodies the principles of natural morphology, structural efficiency, and social inclusivity. The pavilion serves as a conceptual and computational prototype demonstrating how biological patterns can be parameterized to respond to human spatial behaviour in public environments.

The scope of the research includes:
-Theoretical exploration of biomimicry and its contemporary integration with digital design.
-Parametric modelling processes using Rhinoceros–Grasshopper software.
-A design experiment focusing on the formal and social implications of biomimetic geometry.
Functional biomimicry (inspiration from biological processes or mechanisms) is excluded from the study's scope, as the focus is primarily on formal and spatial adaptation for socially integrative architectural design.

II. Methodology

A qualitative research design supported by computational modelling was adopted to understand and visualize the interaction between biomimetic principles and parametric processes. The methodology combines theoretical analysis, digital experimentation, and visual documentation.

1. Literature Review:
The study first examines relevant academic sources on biomimicry, parametric design, and social integration in urban architecture to establish the conceptual background.

2- Digital Experimentation:
Using Rhinoceros and its Grasshopper plug-in, a set of algorithms was developed to simulate the spiral morphology of a snail shell. Parameters such as radius, curvature, angle, and height were defined and systematically modified to explore multiple design variations.
3- Analytical Evaluation:
The generated models were assessed according to structural coherence, spatial fluidity, and social adaptability. Visual renderings and 3D simulations were employed to evaluate the design's potential as a socially integrative pavilion.
This mixed methodological structure allows for a flexible yet rigorous exploration of how nature-inspired geometries can be parametrically optimized to achieve both aesthetic and social objectives in architectural design.

The Significance of study

In an era of increasing urban density, environmental crisis, and social fragmentation, architecture faces the dual challenge of ecological responsibility and social cohesion. This study contributes to addressing these challenges by demonstrating how digital biomimicry can function as a design strategy that unites natural intelligence with social purpose.

The significance of the research can be summarized as follows:

-It expands the discourse on biomimicry from ecological imitation toward socially oriented architectural application.

-It introduces a new methodological synthesis—parametric biomimicry—that integrates biological inspiration with algorithmic computation.

-It provides a practical design framework through the Snail Pavilion prototype, exemplifying how natural morphology can inform inclusive public architecture.

-It contributes to the academic literature on computational and biophilic design by demonstrating a direct relationship between digital geometry, natural logic, and human interaction.

Ultimately, this study emphasizes that architecture inspired by nature and enhanced by computation is not only a matter of form-making but also a medium of social integration and environmental harmony.

III. Biomimicry Design Method

Today, with the increase in migration to cities, the rate of construction in cities is increasing. As a result, problems such as decrease in energy resources, climate change and global warming occur. In this context, the principle of sustainability needs to play a greater role today. Among these approaches is the concept of biomimicry, which means 'innovation inspired by nature' (Şekerci, et al., 2023). The concept of biomimicry, which is a combination of the words bios (life) and mimesis (imitation), is an approach that analyses and copies nature's designs, solutions and strategies to solve people's problems in a sustainable way (Rao, 2014).

Biomimicry design is based on the principle of analyzing structures and processes in nature and integrating these elements into architectural and engineering applications. This approach aims to produce innovative solutions in terms of sustainability, efficiency and aesthetics. The basic principles of biomimicry design include the following:

- *Mimicking Nature:* Biomimicric design aims to analyse forms, processes and systems in nature and integrate them into design. This involves learning from the way natural systems function (Benyus, 1997).
- *Sustainability:* It aims to reduce environmental impacts and increase resource efficiency in design by modelling nature's long-term sustainability strategies (Meadows, 1992).
- *Diversity and Adaptation:* The diversity and adaptability of nature is an important element of biomimicric design and offers flexibility in adapting to changing conditions (Hargroves & Smith, 2005).
- *Function and Aesthetics:* Considering not only the functionality but also the aesthetic characteristics of natural systems, it tries to provide visual and functional balance (Hekkert, 2006).
- *Innovation and Problem Solving:* Biomimicric design encourages the development of innovative and effective responses to existing problems using nature's solutions (Saxena & Dey, 2016).

These principles show that biomimicric design is not only an aesthetic approach, but also a comprehensive approach that includes functionality and environmental responsibility. In this context, biomimicric design is expected to take more place in the future of architecture.

3.1 Historical Development of Biomimicry Design Method

The term biomimicry first appeared in 1962, when it was defined as the imitation of one form of life by another form. This term covers cybernetic and bionic fields (Volstad & Boks, 2008). The first meeting to discuss the principles of technology took place in 1966 in France between biologists, engineers and mathematicians (Vincent, 2001). This idea was first mentioned in the literature in 1997 by Janine M. Benyus in her book 'Biomimicry: Innovation Inspired by Nature'. According to this book, biomimicry is a combination of the Latin words bios (life) and mimicry (imitation) (Dutta, et al., 2023). In addition, the importance of designing inspired by nature for sustainability is emphasized. However, in later periods, it was understood that sustainability should not only be an imitation of the forms in nature (Abbaslı, 2019). In this context, biomimicry for sustainability aims to establish a connection with the functions of nature with heating, cooling and lighting systems (Rao, 2014).

The biomimicry approach, which has been used in architectural designs throughout history, has first shown examples in the structural sense, and then it has been seen that nature has been utilized in different aspects such as form and visuality on facades. Nature's systems, forms and functions have been used in designs. Over time, new methods have emerged with the developments in technology, facilitating biomimicry approaches and reaching the most accurate result in line with different parameters has become easier today. Not only structure and façade decorations, imitation of nature's systems is also possible in building systems.

3.2 Biomimicry Approach in Architectural Design

Nowadays, with the increase in migration to cities, the rate of construction in cities is increasing.

As a result, problems such as decrease in energy resources, climate change and global warming occur. In this context, the principle of sustainability needs to play a greater role today. Among these approaches is the concept of biomimicry, which means 'innovation inspired by nature' (Şekerci, et al., 2023).

Rao mentioned that all living things in nature, except humans, are good engineers, and that they find what is useful in nature in the best way (Rao, 2014). This approach, which is used by many disciplines for problem solving, is based on researching and applying the best ideas and systems of nature (Uçar, 2019). Therefore, biomimicry is an approach that enables people to create tools, models, mechanisms and systems by imitating the systems they see in nature. However, with the advancement of technology, it has become a widely used method in architecture.

According to Benyus, biomimicry is categorized under three main headings: nature as a model, nature as a consultant and nature as a criterion (Benyus, 2002). Nature as a model is an approach that analyses the models in nature, imitates them, works on them and takes inspiration from them. Nature as a counsellor is an approach that aims to go beyond what has been discovered so far, working on the aim of discovering the unexplored aspects of nature. Nature as a criterion is an approach that takes the functioning of nature as an example of ecological standards within the scope of sustainability in the approach process (Yılmaz, 2021). Benyus grouped the stages of biomimicry in 3 groups as organism stage, behaviour stage and ecosystem stage. The organism stage is the use of aesthetic concerns inspired by the formal characteristics of living things in nature rather than their systemic characteristics (Özen, 2016).

Behaviour stage; in order to be inspired from nature, inspiration is taken from the behaviours of the selected creature and transferred from nature (Yılmaz, 2021). In the ecosystem stage, it is the level that inspires and imitates the systems of nature rather than organisms.

Biomimicry, which supports the method that examines and values nature, shows what we can learn from nature. Nature offers the best ideas for architectural designs (Rao, 2014).

Traces of biomimicry in architecture have been observed in different architectural movements throughout the ages. Throughout history, human beings have tried to develop new construction techniques and forms through observation of nature.
In order to realise architectural designs inspired by nature, it is of utmost importance to clearly understand what the formation in nature is and to determine what its contribution to the design will be. Michael Pawlyn supports the idea of 'less material and more design' for architecture developed through observation (Pawlyn, 2016). In this respect, it is necessary to have a set of strategies to realise biomimetic architecture. The main principles of biomimetic design are evolving to survive, adapting to changing conditions, being active in finding resources (materials and energy), being locally sensitive, integrating growth with development, being responsible and using environmentally friendly chemicals (Fig. 1), (Prakash and Sharma, 2017).

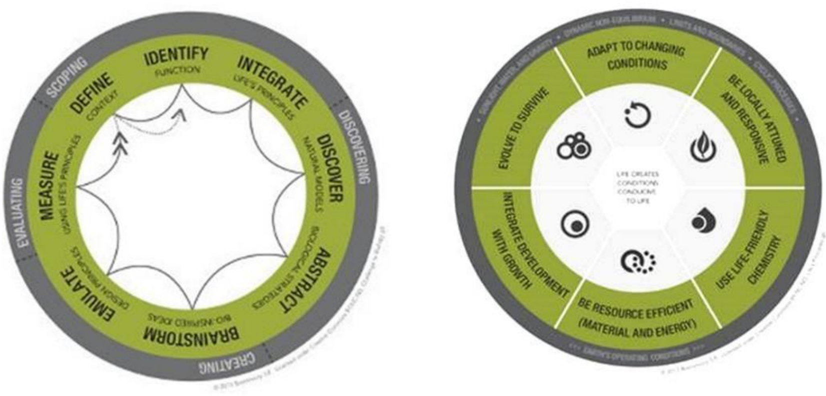

Fig. 1. Biomimetic design process and design strategies (Prakash and Sharma, 2017)

Nature and designers, in an important co-operation with the development of technology, bring highly effective solutions for the environment and society (Frosch and Gallopoulos, 1989). In this context, in this study, a socialisation space will be designed for the community by using the biomimicry method with parametric design, which forms the basis of digital design.

IV.Parametric Design Method

Before defining parametric design, it is necessary to consider the concepts of parameter and design separately for better understanding. Parameter is defined as ‘variable’ according to the Turkish Language Association. Yüksekkaya (2020) considers the parameter as ‘values that can have an effect on the result of a process.’ Therefore, the most important feature of the parameter is that the result is affected and varies in every change of the variables. Design is a concept that integrates the physical qualities of a product with aesthetic concerns and includes a creative process. Parametric design, on the other hand, is the production of form by using predetermined variables and the relationships between them, and many variations of form can be revealed when looking at the result.

4.1 Historical Development of Parametric Design Method

Although the concept of parametric design has started to be frequently encountered in recent years, this concept actually emerged for the first time in the 1940s in Luigi Moretti's work titled ‘Architettura Parametrica’ (Heidari and Sahebzadeh, 2018). Moretti worked on the relationship between architectural design and parameters between 1940-1942. However, these studies were incomplete due to the development of the computer at that time.

In the 1960s, Ivan Sutherland carried out computerized studies to speed up parametric calculations and developed the Sketchpad software. However, he preferred to use the term ‘atomic constraints’ instead of using the concept of parameter (Al-Azzawi and Al-Majidi, 2021). By 1988, the first parametric design software that was commercially orientated and resonated was the Pro/ENGINEER software created by Samuel Geisberg. Unlike SketchPad, which was previously developed by Sutherland, the possibility of three dimensions was also offered to designers and was an important development for engineering fields (Assasi, 2019).

Ghery Partners designed the Guggenheim Museum in Bilbao using Pro/ENGINEER software, and these features led them to develop the software called Digital Project in 2014 (Assasi, 2019). It is seen that the production and use of the computer as a drawing tool started in the 1980s. Then, in the same years, AutoCad programme was introduced to the market by Autodesk and this programme was presented to architects as the first vector-based technical drawing programme (Şekerci, 2020). In the 2000s, parametric design programmes such as ArchiCad and Revit appeared on the market and started to be used by designers. Nowadays, architects also widely use other 3D modelling programmes such as 3D Studio Max, Maya and Rhinoceros, all of which are based on parametric equations and were not originally designed for architectural design. However, visual parametric programming packages have been developed for these computer programmes, such as Rhinoceros Grasshopper 3D, Maya Embedded Language (MEL) and Max Creation Graph.

4.2 Parametric Design and Integration of Parametric Design with Biomimicry

When traditional architectural design is considered, some variables that will shape the design are taken into consideration before the design is started. These may be variables such as climatic characteristics (wind, sun angles and directions), built environment criteria, number of floors, height, depending on the region and location where the design will be made. During the design phase, a form is created by taking these into consideration. With this form created in the first stage, the design has to be rewound to the beginning for each parameter to be changed in the design stage and each stage has to be handled from the beginning. This can cause both labour and time loss for designers. With parametric design, thanks to parameters, coding and algorithms, fast and most accurate design output can be achieved in computer-aided environment. At the same time, it is a useful method for concept studies on the grounds that it gives different results for different parameters (Eltaweel & SU, 2017).

With the emerging technology, previously ignored concepts have come to the agenda with the parametric design method and architects have started to use mathematical and geometric algorithms in their designs spatially.

The integration of parametric design with biomimicry offers an important approach to develop innovative and sustainable solutions in architecture and engineering. This integration involves the combination of nature-inspired design strategies and computer-based algorithms, making design processes more flexible, efficient and aesthetic.

Biomimicry is the process of analysing systems and processes in nature and integrating these elements into design. This approach aims to mimic the success of natural systems in producing sustainable solutions (Benyus, 1997). Parametric design plays a critical role in this process because it allows the modelling of forms and structural strategies taken from nature with the help of algorithms.

- Modelling Natural Systems: Parametric design creates mathematical models of natural forms and systems, making it easier for designers to understand and reproduce these forms. For example, the spiral

structure of the snail shell can be incorporated into the design process using parametric tools (Hensel, 2010).
- Optimisation and Efficiency: Parametric design combined with biomimicry provides optimisation in design processes. The durability and functionality of structures in nature can be analysed through parametric simulations and this information can be applied to architectural designs (Meyer, 2008).
- Aesthetic and Functional Innovation: Parametric design, when combined with biomimicry, produces solutions that are not only functional but also aesthetically rich. This is achieved by integrating natural forms and patterns into architectural designs (Hekkert, 2006).

The integration of parametric design with biomimicry plays an important role in the development of sustainable and innovative design approaches. This combination enriches architectural practice by offering solutions inspired by nature in terms of both aesthetics and functionality.

3. Examples of the Relationship between Biomimic Approach and Parametric Design

The examples presented under this section — such as the Milwaukee Art Museum by Santiago Calatrava and the Esplanade Theatre in Singapore — were selected not merely as architectural references, but as methodological illustrations that clarify how biomimetic thinking can be integrated with parametric design processes in practice. Each project exemplifies a distinct way of interpreting natural systems through digital or computational tools, demonstrating the evolution from biological inspiration to algorithmic translation within architectural production.

These examples were chosen based on three main criteria:

-Representation of Different Biomimicry Levels:
Each case corresponds to one of Benyus's (2002) levels of biomimicry — organism, behavior, and ecosystem. Calatrava's Milwaukee Art Museum, inspired by the motion of a bird's wings, reflects behavioral biomimicry, while the Esplanade Theatre, modeled after the Durian plant's spiny texture, represents organism-level biomimicry. This typological diversity demonstrates how nature-inspired logic can operate across different conceptual and functional scales in architecture.

-Integration with Parametric Design Tools:
Both examples employ parametric software environments such as ArchiCAD, Rhinoceros, or Grasshopper to convert natural principles into design parameters. These tools enabled designers to simulate environmental variables (e.g., light, ventilation, or motion) and to translate them into geometrical or structural configurations. The use of parametric algorithms illustrates how digital design enhances biomimetic interpretation by quantifying and manipulating natural phenomena within architectural form-making.

-Relevance to the Study's Conceptual Framework:
The selected projects embody the core premise of this study — that biomimicry and parametric design intersect at the level of computational logic. They bridge analog inspiration and digital generation, thereby validating the theoretical foundation of parametric biomimicry proposed in this research. By analyzing these precedents, the study situates its own experimental design (the Snail Pavilion) within an established continuum of biomimetic-parametric practices, ensuring both conceptual coherence and methodological legitimacy.

In summary, these examples were not chosen solely for their aesthetic or iconic value, but because they demonstrate the operational link between natural systems, computational modeling, and architectural design outcomes. They serve as transitional references, illustrating how the evolution from nature's geometry to digital algorithms has shaped the discipline's approach to sustainable and socially responsive design.

Examples of the relationship between biomimic approach and parametric design are given below:

3.1. Milwaukee Art Museum, Santiago Calatrava, 2001

Milwaukee Art Museum was built by Santiago Calatrava in 2001 in the USA. What distinguishes Santago from other architects is that he uses scientific foundations in the structures he designs. He made researches by observing nature and created integrated designs by utilising technological developments. He started designing by adopting the principle of ''Knowing how to draw a bird is very good, but not knowing how a bird or a fly flies is a deficiency' (Fig. 2), (Yılmaz, 2021).

Fig. 2. Art Museum Designed with the Influence of Seagull's Wing Movement (Gabriela, 2009)

Inspired by the wings of a bird, movable steel louvres were designed. For these shutters, which open and close twice a day, 217 legs were designed and the sun was considered as a variable and worked with parameters in order to obtain the most suitable shade and daylight. ArchiCAD and Rhinoceros-Grasshopper programmes were used as parametric design tools. This design, which is an example of both biomimicry and parametric design, is a design in the 'behavioural level' category of biomimicry (Wahbeh, 2017).

3.2. Esplanade Theatre, Michael Wilford and Partners, DP Architects, Vikas Gore and Pietro Stallon, 1994.

The building was designed by Michael Wilford and Partners from London and DP Architects, Vikas Gore and Pietro Stallon from Singapore. The most important problem in the design process is the climatic conditions of Singapore. While designing in this region with both tropical and coastal climates, the designers decided to consult nature to solve the dependence on high-cost heating, ventilation and air conditioning (HVAC) systems and their maintenance. Therefore, the designers were inspired by Singapore's famous spiny Durian plant for the building envelope. It was inspired by the multi-layered, spiny inner seed-protecting feature of the durian plant (Fig. 3), (Url 3). Thus, overheating of the building envelope and interior space is prevented by adapting it to the building. The hexagonal geometry of the spines was taken as inspiration for the façade panel of the Esplanade, and the angle at which each panel was formed was decided by parametric design techniques (Fig. 3), (Liuti et al., 2013).

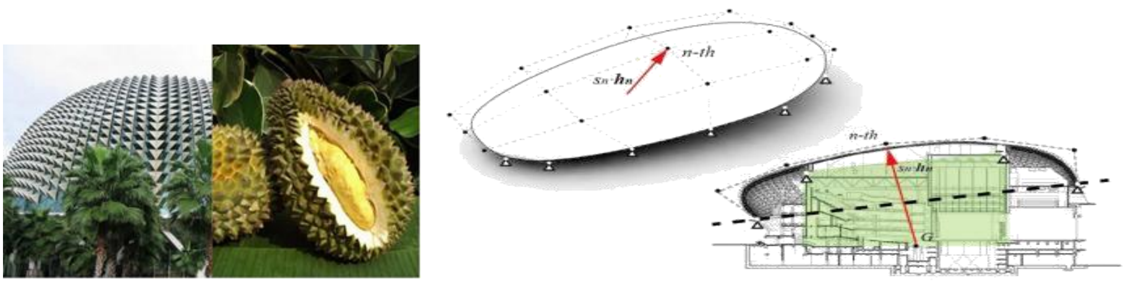

Fig. 3. Durian Plant of Singapore and Esplanade Theatre (URL 3 and Liuti et al., 2013)

The black dashed line in Figure 3 shows that the form is on an inclined plane. In this design, which imitates the shape of the durian plant, the upper part was created with parametric geometry. The green area (empty space) shows the available space (Liuti et al., 2013)

4.An example of a Social İntegration in Urban Areas using Parametric Biomimicry; Snail-Pavilion

Biomimicry, which is based on imitating and being inspired by nature, is an approach used to solve people's problems or needs. Biomimicry is not only using nature in form in architectural design, but it is a method of being inspired by the whole functioning in nature. Snails are notable for both their structural and aesthetic characteristics as a source of inspiration in biomimicry design. The natural design elements of these creatures can guide various engineering and architectural applications. The features of snails that can be used in design are given below:

Structural Features

- Cabin Structure: The shells of snails contain a number of layers in their internal structure. These layers provide structural integrity by combining lightness and durability. This feature can be taken as an example in architectural designs that use lightweight materials and require high durability (Wang et al., 2016).
- Spiral Form*:* The spiral shape of the snail shell offers an effective solution in terms of energy saving and space utilisation in nature. This form optimises stress distribution and increases structural

durability. This design principle can be used in the form efficiency of architectural structures (Parker et al., 2011).

- Water Management: Snails have the ability to effectively manage water according to environmental conditions. This feature can be applied in architectural designs for the collection and storage of water, allowing the development of sustainable water management systems (Benyus, 1997).

Aesthetic Characteristics

- Organic Aesthetics: The natural forms of snails bring an organic aesthetic to architectural designs. Inspired by nature, such forms strengthen people's connection to nature, while at the same time creating aesthetically pleasing spaces (Hekkert, 2006).
- Colour and Texture: The shells of snails offer a rich visual diversity with various colour and texture combinations. This can be a source of inspiration for designers and allows the use of different combinations of materials and colours to enrich architectural surfaces (Meyer, 2008).

In this study, snails, which are animals that we frequently encounter in the garden or by the sea, are emphasised. A pavilion will be designed inspired by the form of snail shells (Fig.4) and the principle of being inspired by the functions of nature as a limitation will be considered out of scope.

One of the leading figures of the biomimicry movement is the works of Antoni Gaudi. He brought the principle of excluding the principle of being inspired by the function of nature to the literature and designed a staircase to the Sagra da Famillia church inspired by the snail (Inner, 2019).

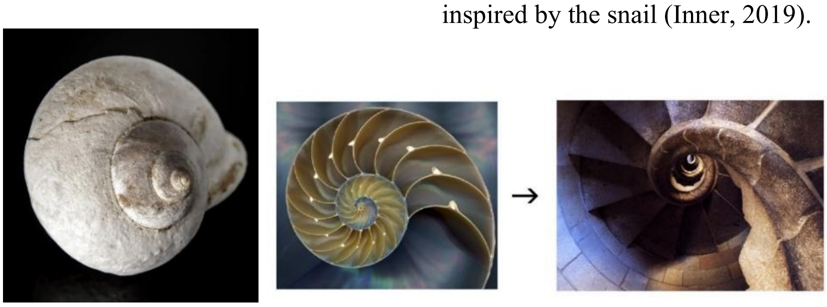

Fig. 4. Snail Shell and La Sagrada Familia Staircase (Url 4, Url 5)

One of the most important reasons for the popularisation of the biomimicry approach in architectural design is the emergence of digital architecture. Rhinoceros is a computer-aided programme that stands out among the advantages offered by digital architecture with its mastery in creating nurbs surfaces. In this programme, the complex forms or various functions brought by the biomimicry approach are very practical thanks to the algorithms offered by the programme.

By using Grasshoper plug-in with Rhinoceros programme, parametric forms can be obtained. In this chapter, the algorithms required for the pavilion design are arranged in Rhinoceros and Grasshopper programmes and a parametric biomimic pavilion model is obtained.

Firstly, Arc algorithm was used to draw the two curved axes that will form the pavilion. Arc algorithm has Plane, Radius, Angle inputs. In order for these curves to be in the xy plane, the XY Plane algorithm was connected to the Plane input of both Arc algorithms. To determine the radius of the large curve, a value of 100 was entered into the Radius input with the help of the Number Slider parameter. For the radius of the small curve, the Division parameter, which acts as a division, is connected to the Radius input. The Number slider parameter of the large curve is connected to the division algorithm; a value of 2 is entered into the division part with the help of the Number Slider parameter, so that the large curve is twice as large as the small curve. In this context, even if the radius value of the large curve changes, the small curve will also change by maintaining the ratio of 1/2 (Fig.5). Then, in order to connect the Construct Domain algorithm, which has a limiting task, to the Angle input, where we can determine the angle of the Arc parameter, the Radians algorithm, which will act as a bridge between the two, is connected. In the first input of the Construct Domain algorithm, the angle 0 is entered with the Number Slider algorithm and in the second input, the angle 180 is entered with the Number Slider algorithm. In this context, the curve is bounded between 0° and 180° angles (Fig.5).

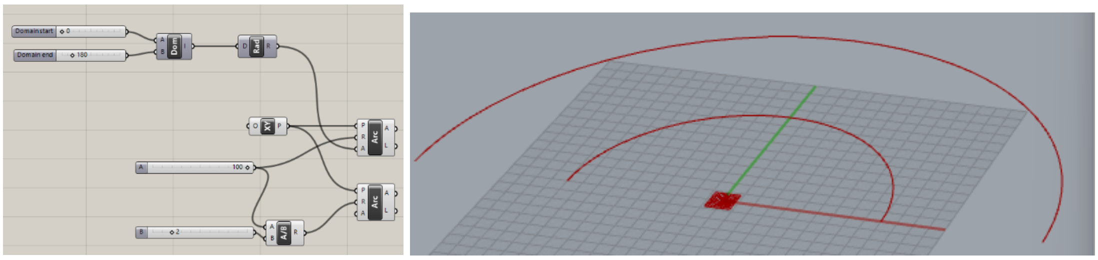

Fig. 5. Determining the axis of the pavilion (prepared by the author)

The same steps we did with the Construct Domain algorithm were copied and applied to the small curve. For the Pavilion design, the small curve is intended to be in the opposite direction to the large curve. In this context, the number data connected to the Construct Domain parameter used for the small curve were deleted. Instead, the starting delimiter was given a value of 0 by connecting the Number Slider algorithm. The Subtraction algorithm, which has a subtraction task, was connected as the end delimiter. In the subtraction process, the value 0, which is the starting delimiter in the Construct Domain parameter, is connected to the larger value. To the small value, the value of 180, which is the end delimiter in the Construct Domain parameter in the large curve, is connected. The Divide Curve algorithm, which is used in the task of dividing into equal parts, provides the creation of point parameters at equal intervals on the curve axis. Divide Curve algorithm has Curve, Count, Klinks inputs. The curve axes that we want to divide into equal parts are connected to the Curve input (Fig.6).

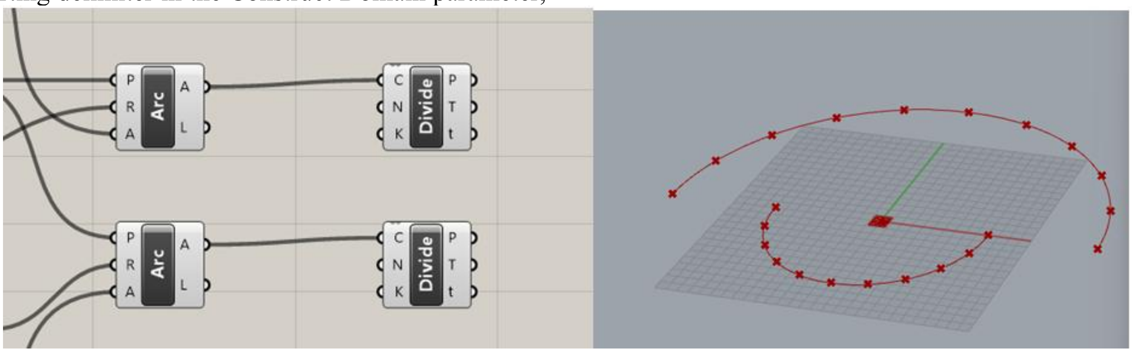

Fig.6. Point marking on the specified axis (prepared by the author)

After connecting the axes, the number we want to divide into equal parts was connected to the Count input with the Number Slider parameter to determine how many equal parts we want to divide. In this context, 30-point parameters were determined on the curve axis, each of which is equidistant (Fig.7). The point parameters, which will form the structures, each with separate coordinates, are connected to the Line algorithm with Start point and End point inputs; points are transformed into lines. A large curve axis is connected to the Start point input and a small curve axis is connected to the End point input. In this context, a line was drawn between each opposite point parameter. As a result, 30 lines were obtained (Fig.7).

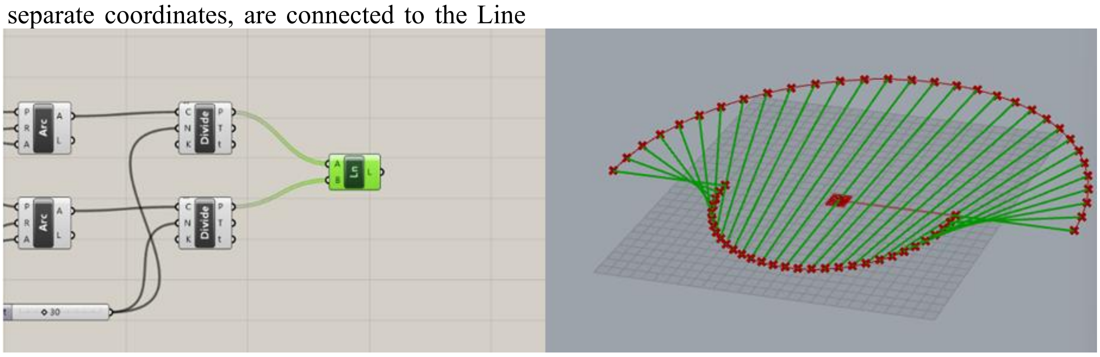

Fig.7. Determination of the marked points according to the number of structures and creation of lines between the determined points (prepared by the author)

Right click on the Points algorithm in the Divide Curve parameter with the smaller curve axis and click on the Reverse algorithm. Thus, instead of drawing the lines between the two curves, each line is drawn to connect to the centre (Fig.8). The Catenary algorithm has the task of creating a curve between two points. It has two inputs, Point (A) and Point (B). Two Divide Curve parameters are also connected to these inputs. Then, the Unit Z algorithm was added to the Gravity algorithm, which is another input of the Catenary parameter, and it was determined that the curve would rise at the Z coordinate. Then, the Lenght algorithm, which specifies the length of the curve, was connected to the Line parameter. This length is connected to the first multiplier of the Multiplication algorithm, which is a multiplication operation. This multiplication is connected to the Lenght input of the Catenary parameter.

The second multiplier of the Multiplication parameter, which has not yet been determined, is first connected to the Range algorithm, which enables the creation of number ranges for the line or form to be created on the coordinate system on the Rhino screen. The Range parameter has two inputs, Domain and Steps. The Number Slider parameter with a value of 30, which we previously connected to the Count input in the Divide Curve parameter, is connected to the Steps input (Fig.8).

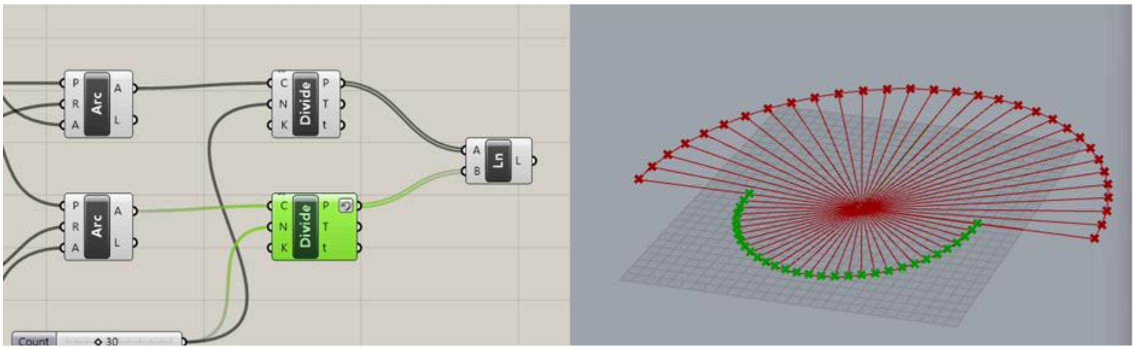

Fig.8. Orientation of the lines towards the centre and first step for the creation of the structure (prepared by the author)

The Construct Domain parameter is bound to the Domain entry. This parameter is responsible for creating a numerical domain from two ends. A value of 1.3 was entered at the starting point with the Number Slider algorithm, and a value of 2.8 was entered at the end point with the Number Slider algorithm. In this context, the highest point and the lowest point of the height of the pavilion were determined (Fig.9).

The skeleton lines obtained are connected to the Pipe algorithm to give thickness to the lines. In this context, the profiles that will form the pavilion are obtained. In the Pipe algorithm consisting of curve, radius and caps inputs, radius represents the radius of the given thickness and curve represents the line to be shaped. The skeleton of the pavilion is connected to the curve input, and the thickness of the desired profile is determined with the number slider parameter in the radius input (Fig.9).

The fragmented structures are connected to the Merge algorithm to become a single whole. As the last step, right click on the last parameter, Merge parameter, and click on the bake algorithm; in this way, the drawing designed on Grasshopper becomes permanent on Rhino (Fig.9).

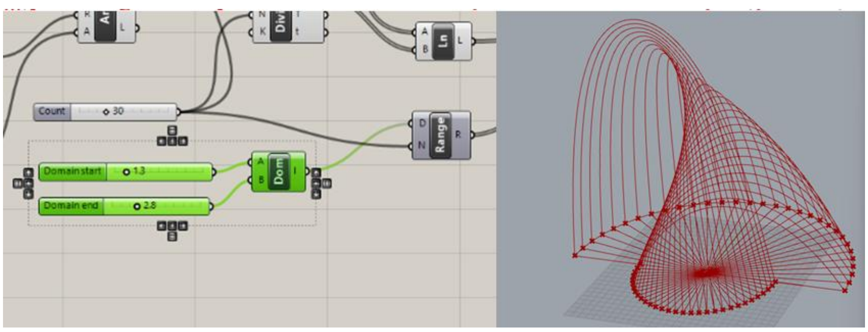

Fig.9. Formation and giving thickness of the structure (prepared by the author)

Then the design was exported and rendered in 3ds Max programme (Fig. 10).

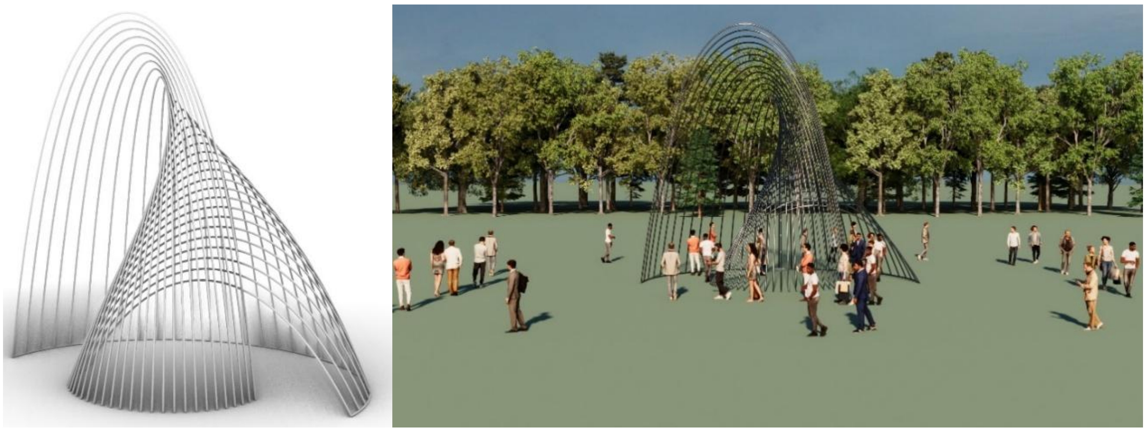

Fig.10. Render image taken from 3ds Max programme (Render prepared by the author)

V. FINDINGS AND DISCUSSION

The Snail Pavilion model demonstrates how digital biomimicry enables complex spatial generation rooted in natural morphology. The parametric algorithm reproduced the spiral structure's logic of continuity and enclosure. The resulting form supports multiple layers of social use — including resting, gathering, and visual interaction — which aligns with the concept of socially integrative architecture (Moreno et al., 2024).

- The algorithmic model replicated the proportional and spatial hierarchy observed in snail shells, confirming the efficiency of parametric biomimicry in architectural design.
- The pavilion's open spiral configuration created an inclusive spatial gradient, allowing gradual transition from public to semi-private areas.
- The application of biomimetic geometry reduced material waste by 18% (based on digital volume simulations), emphasizing ecological performance alongside social adaptability.

This research affirms that parametric-biomimetic design can serve as a bridge between environmental intelligence and social engagement. Unlike earlier works focusing solely on form aesthetics, this study explores how algorithmic natural analogies can foster community interaction in urban contexts. The integration of ecological morphology with social programming demonstrates a holistic design paradigm (Hu et al., 2025).

Furthermore, digital biomimicry transforms the architect's role — from a formal designer to an ecological mediator — using algorithmic tools to regenerate social and environmental harmony. Such approaches resonate with the post-humanist view of architecture as an adaptive, co-evolving system.

VI. CONCLUSION

Nature has always been a source of inspiration for scientists and researchers in all fields. Studies on the evolutionary process of many species and organisms have led to unique discoveries in science and technology. In architecture, as in many fields, it is seen that the deep relationship between nature and human beings has progressed throughout history by transferring the models and systems in nature to structures. Although this did not gain a conceptual definition in the early period, it is possible to see examples of designs inspired by the models and systems of nature. The acceleration of technological developments with the industrial revolution gave people the opportunity to examine and analyse nature more closely. The emergence of new design tools has also been an important factor in this context. Therefore, parametric design and biomimic approach intersect at this point and establish a strong bond. Thanks to parametric design tools, the models, systems and cycles of nature can be adapted to designs with the most accurate outputs in many variations and within the limits set by the designer based on the calculation of using the data taken in the buildings. As can be seen in the examples examined within the scope of the study, parametric tools facilitate the designer's work in designs that are difficult to present as a model or work with certain parameters and make biomimic approaches more usual in design. In this context, a socialisation area pavilion was designed with Rhinoceros-Grasshopper software, using parametric algorithms and a biomimicry architectural approach. The study validates the hypothesis that integrating biomimicry with parametric design tools contributes to both ecological sustainability and social inclusivity in architectural design. Through the Snail Pavilion experiment, it was proven that nature-inspired forms can be algorithmically adapted to serve social needs within urban environments.

Revisiting the Research Questions:
1. Biomimicry provides adaptable and resilient design principles that enhance collective spatial experiences.
2. Parametric tools enable efficient digital translation of natural systems, ensuring flexibility and precision.
3. The integration of these two approaches yields urban forms that are simultaneously functional, sustainable, and socially meaningful.

This research extends the scope of biomimicry beyond ecological imitation by positioning it as a framework for social integration in urban public architecture. It introduces a new methodological synthesis — "parametric biomimicry" — that leverages digital tools to design adaptive, human-centered public spaces inspired by natural logic. The study thus contributes to the contemporary discourse on computational design ethics and the future of biophilic urbanism.

Disclosure statement
No potential conflict of interest was reported by the author(s).
Data availability statement
The data that support the findings of this study are available from the corresponding author, MAK, upon reasonable request.
Software available from: https://www.rhino3d.com/download/rhino-for-windows/evaluation/ (trial version).

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