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Analysing morphogenetic design approaches in the context of hypothetical housing examples

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Abstract

Conceptual approaches that systematically integrate ecological reasoning with algorithmic design processes have gained increasing attention in theoretical discussions on architectural practice. However, a significant gap remains in terms of their application, particularly within the context of housing architecture. In response to this theoretical gap, this study aims to evaluate the algorithmic orientations of designers who transform their spatial inquiries into an ecological organization through hypothetical housing examples. This evaluation is framed through the concept of morphogenetic design—a biologically informed architectural approach in which form and space evolve not through predetermined templates but through generative, adaptive, and systemic processes. Accordingly, the study addresses two main research questions: 'The potential impact of morphogenetic design on residential buildings' and 'Integration of morphogenetic design into housing construction processes'. The study employed a qualitative research design and the literature review method to answer the research questions. The research sample consists of four hypothetical housing projects: Embryological House, Multistory Apartment Building, Molecular Engineered House, and The Fab Tree Hab. These projects were developed using morphogenetic design approaches in 2000 and beyond. In order to collect data from the main mass in an easy and fast way, Homogeneous sampling method, one of the purposeful sampling types, was preferred. In this context, the 'descriptive content analysis method' was preferred to analyse the data obtained in the research and the data was analysed in two stages. In the first stage, descriptive analysis was carried out and the general trend was determined by examining the qualitative studies that could answer the research questions. In the second stage, content analysis was carried out and the data obtained were organised and interpreted according to the parameters set by the researcher. The analysis indicates that morphogenetic design has the capacity to substantially transform the formal, functional and ecological dimensions of future residential buildings. Digital design methods, biologically inspired production techniques and user-participatory design strategies have rendered it feasible for buildings to self-renew, establish symbiotic relationships with their environment and adapt to various living scenarios. This process is characterised by the integration of sustainability and user experience across multiple stages, ranging from design to construction.

Keywords: embryological house, fab tree hab, molecular house, morphogenetic design, multistory apartment

1. Introduction

Housing is a phenomenon that reflects social values and is a crucial element of architectural practice and thought discussions. It establishes the built environment as an effective spatial value (Şensoy & Özaslan, 2020, p. 281). In this context, housing meets the need for shelter, which is the most irreducible element of daily life, and thus shows the quality of being a basic component of the built environment (Riley, 1999, p. 9). The content of housing has been influenced by changes in people's understanding of life based on the prevailing knowledge of the time. The production and spatial organisation of housing can be discussed through hypothetical propositions. The act of sheltering is the most important aspect of living possibilities and is the common content of new design approaches emerging for the current situation. The negative consequences of industrialisation, such as uncontrolled population growth, excessive urbanisation, and reduction of

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natural areas, have led to a search for solutions. This has resulted in the proposal of many designs that aim to address the problems caused by industrialisation in social life and the physical environment. Nature has been a guiding, informative, and inspiring source throughout the evolutionary process of the human species on earth. Understanding nature has directly or indirectly influenced the accumulation of knowledge produced by humans. This is because nature is inherent in all activities resulting from human physical or mental activity. On the other hand, various factors significantly impact the relationship between our understanding of nature and architectural design theories. These factors include religious beliefs, scientific advancements, technology, and human subjective experiences. These parameters establish the theoretical background of the relationship between natural philosophy, science, and architectural discipline, shaping the logical framework of architectural design methodologies. This research evaluates morphogenetic design approaches within the context of housing problems. These approaches reflect technological and scientific developments of the period. The potential of these approaches to solve housing problems has not yet been sufficiently researched.

1.1. Problem

The main problem of this research is to explore the impact of morphogenetic design approaches on housing production processes and to demonstrate these effects through hypothetical designs. The study analyses the applicability, aesthetic values, and sustainability factors of morphogenetic design in housing production using specific examples. Furthermore, the potential contributions of this design approach to the housing industry are evaluated.

1.2. Purpose

The objective of this research is to establish a dialogue between the morphogenetic design approach, which is one of the current manifestos in the discipline of architecture, and housing production. The theoretical underpinnings of the morphogenetic approach will be analysed through interdisciplinary relationships. Additionally, the algorithmic orientations of designers who transform their spatial searches into an ecological organization through hypothetical housing examples are comparatively evaluated.

1.3. Questions

The study aimed to answer the following two research questions (RQ1 and RQ2) based on the identified problems:

RQ1: What is the potential impact of morphogenetic design on future residential buildings?

RQ2: How is morphogenetic design integrated into housing construction processes?

1.4. Importance

This study explores the ecological framework established within residential buildings for architectural experimentation, highlighting the location and implementation of morphogenetic design approaches in housing production, predicting the interaction between biology and architecture, and synthesising the wealth of research information currently available to contribute to the existing literature.

1.5. Limitations

The study's limitations are discussed in terms of theoretical and methodological aspects, as well as the internal and external validity of the research. Although a comprehensive literature review was conducted on the research topic, the limited number of scientific studies aiming to establish a dialogue between morphogenetic design approaches and housing production is considered a theoretical limitation of this research. It is important to note that the research was conducted on hypothetical designs rather than implemented projects, which weakened the internal validity of the study. It is also possible that housing production may be affected by other factors beyond the parameters included in the research. The study assessed the impact of factors that were controllable or known. However, it had methodological limitations. The data was collected only from four housing projects developed in 2000 and after, which limits the generalisability of the findings. The study's external validity was negatively affected by the limited sample area.

1.6. Literature Review

While there is a shortage of research directed at forming a connection between morphogenetic design approaches and residential buildings, there are significant studies that explore the topic in its own context and scrutinize comparable issues. This section provides a short summary of the compiled national and international literature on the notion of morphogenetics.

Kolarevic's (2000) study examines how digital morphogenesis is used as a generative tool for deriving and transforming form rather than solely as a representational tool for visualisation. In Hensel et al.'s (2004) research, they discuss morphogenetic design approaches as a development that will affect not only the construction of buildings but also the composition of new materials. In the study carried out by Akyol Altun (2007), the impact of scientific and technological research on the field of architecture was investigated, with a specific focus on the emerging morphogenetic approaches. These approaches are predicted to have a significant influence on the future of architecture, despite currently being viewed as unrealistic. Similarly, İnceköse (2008) questioned the use of natural scientific knowledge in contemporary architectural discourses within an epistemology centred on architecture and biology. In Akbulut's (2009) study, evolutionary design approaches, which assign a distinct role to the designer compared to traditional methods, are viewed as a creative process. Roudavski (2009) examined morphogenetic approaches in comparison to architectural design techniques and analysed the impact of this biological concept on current architectural discussions. Menges' (2012) research associates morphogenetic design methods with exploratory evolutionary computation and features two case studies showcasing the development of spatial morphologies. Erbaş Korur and Dülgeroğlu Yüksel (2013) examine the impact of genetic science on architecture. Vural and Mutlu Avinç (2015) comparatively analyze traditional design methods inspired by nature, morphogenetic, and computational design processes according to life criteria. In the study carried out by Sönmez and Balcı (2020), the concept of form in architecture and the processes of formation were analyzed by contrasting hylomorphism-morphogenesis. Şensoy and Özaslan's (2020) research discusses housing utopias through architectural representations of interdisciplinary proposals that prioritise the sustainability of life. The discussion examines the transformation of utopias, which were incorporated into the field of architecture with industrialisation, into contemporary utopian proposals as a result of the field of knowledge of the time. Bulu and Kavut's (2021) interdisciplinary research explored the application of the concept of morphogenesis in science fiction cinema, specifically within the fictional spaces of the movie Annihilation. On the contrary, Özer Yaman's (2022) research considered the role of morphogenetic design approaches in architectural education. These philosophical and interdisciplinary discussions—such as hylomorphism, utopia, and epistemology—are included not as isolated theoretical elements, but as complementary perspectives that reveal how morphogenetic thinking expands the conceptual scope of housing design. In this way, the literature review integrates theoretical, computational, and discursive layers that shape the foundations of this study.

The literature suggests that morphogenetic design approaches, which are currently being discovered and developed for the discipline of architecture, stand out in relation to biology and genetics, evolving design processes, sustainability-oriented utopian thought and representations in science fiction cinema. Furthermore, it can be inferred that morphogenetic design approaches are an important predictor for the future of architectural education and the profession. Based on this literature, the present study positions itself as a conceptual and analytical extension that explores how morphogenetic design approaches—previously discussed in relation to digital tools, biomimetic principles, and educational frameworks—can be critically examined through the lens of speculative housing design. The diversity of cited sources enables a multi-dimensional grounding for interpreting design strategies, while the selected housing examples serve to contextualize these theoretical perspectives in spatial and programmatic terms. Rather than presenting a general literature synthesis, this study attempts to operationalize and recombine these strands of thought into a specific interpretive model relevant to contemporary architectural experimentation.

2. Theoretical Framework

Philosopher and historian Robin George Collingwood divided the history of natural philosophy into three periods: Ancient Greek, Renaissance, and Modern periods. In ancient Greece, nature was often personified as a living being regulated by a competent intellect. However, during the Renaissance, it was commonly understood as a machine controlled by God. In contrast to the mechanical and static understanding of the Renaissance, the modern period was conceived on the basis of change and evolution (Collingwood, 1945, pp. 8-9). The theory of evolution, proposed by British biologist and natural historian Charles Darwin, states that the key to survival in the natural environment is adaptation to existing physical conditions. This theory highlights the fact that the ecological system is in a constant state of development due to ever-changing living conditions. Nature is described as a system that defines relationships, produces solutions to problems, and can organize itself. Furthermore, the continuous evolution of nature suggests that the concept of design created by nature is also constantly changing and developing (Von Sydow, 2012, p. 42).

According to Portoghesi (2000, p. 10), the human approach to incorporating nature into architecture involves creating unique conditions that correspond to different levels of interaction between the two. This process is dynamic in nature. In this framework, the definition of the communication between the natural and the artificial allows for a solution to the design of a specific situation or structure that emerges in line with multifaceted requirements. The use of tools and methods that reference design processes allows for speculative production approaches to emerge within the architectural discipline. This process allows designers to draw structural conclusions about natural systems and establish the appropriate experimental environment through the morphological approaches obtained.

At this point, nature contains a wealth of information for designers within the ecosystems it hosts. This information is useful for producing efficient and strong designs for biological structures and provides constructive guidance. In this framework, the design practice being evaluated gains a specific identity by including organic references in the intuitive process. The new meaning produced necessitates the entire design process to work with integrity. In particular, architects can use algorithm-based production environments to test various alternatives in a multidisciplinary setting. These environments are often referred to as 'designing the design process' and are facilitated by digitally mediated organizations. New formal experiments produced with the computational design capability of digital technologies enable architects to collaborate in interaction with different branches of expertise. In this context, computer-aided design orientations have facilitated the development of a new generation of architects who are adaptable to technology and have transformed traditional design approaches. This transformation has made it possible to interpret biological references on an architectural scale and adapt spatial ideas to an ecological organization. Furthermore, it is important to discuss and make sense of the approaches that remain valid on an international scale, considering the historical development of biomimicry. This approach is widely accepted as the predecessor of the morphogenetic design approach and its interaction with design disciplines, as well as its contribution to the architectural profession.

2.1. Biomimicry Overview

The relationship and connection between architecture and nature has raised many questions, criticisms and solutions. Today, there is a new form of design that requires modern man to look to the natural processes found in nature for inspiration. The true potential of these processes, which have existed for decades, has only recently begun to emerge. According to Maglic (2012, p. iv), the philosophy behind living organisms in nature can be used to aid human development, and this is defined as 'biomimicry'. Kennedy (2017, p. 51) defines biomimicry as innovation achieved through the imitation of biological forms, processes, models and systems. The term 'biomimicry' or 'biomimetics' was first used in 1957 by Otto H. Schmitt, a biophysical engineer (Bhushan, 2009, p. 1445). Briefly defined as 'imitating nature', biomimicry as a scientific discipline was introduced by Janine M. Benyus. Janine M. Benyus, a science observer who took into account the suggestion of Robert A. Frosch and Nicholas E. Gallopoulos, who proposed the idea of imitating ecosystems, as the destructive communication of architecture with society and the physical environment became apparent, brought all the information she obtained as a result of her research into the literature with the book 'Biomimicry: Innovation Inspired by Nature', published in 1997.

Benyus, who defines the principles of biomimicry, which is etymologically identified with the combination of the Greek words 'bios' meaning 'life' and 'mimesis' meaning 'imitation' (Benyus, 1997, p. 64), and which aims to produce solutions to human-oriented needs by referring to the ecological system, imitating nature and interpreting the strategies developed by nature, defends the need to see nature as a 'model', 'advisor' and 'criterion'. Benyus also states that the specific solutions that nature provides to the problems it encounters should be considered as an important guide for design processes. These ideas of Benyus have been integrated into many design disciplines and these developments have expanded the meaning of the concept of biomimicry. The idea of building a sustainable environment in harmony with nature by using biological systems also enables the production of new, long-lasting solutions. In this process, understanding, learning and interpreting the complex relationship of living organisms integrated into the ecosystem is seen as an acceptable method to give an idea of how the built physical environment is created. The concept of biomimicry, which defines the process in general terms, is seen as a common design method with sustainable potential, based on imitating the networks of relationships in nature, where each living thing provides mutual benefit.

The basic concept and starting point of biomimicry is that nature develops highly effective and sustainable ways of performing its functions, which can benefit designers when dealing with similar challenges (De Pauw et al., 2014, p. 3). In this respect, biomimicry, which cuts across many different disciplines such as architecture, engineering, chemistry and biology, and operates on the principle of treating them as a common approach, has also inspired countless designers with the collective systems view it offers. In particular, the accelerating growth of global economies based on consumption and the excessive use of resources, which increases with the industrialisation that feeds this chaotic mechanism, have brought sustainability concerns to the fore and contributed to the development of biomimicry, which refers to the designs of nature, which has managed to survive for billions of years without causing any of these concerns. It is in this sense that we can understand man's attempt to protect himself by studying natural phenomena. However, this process often seems to be devoid of real biomimetic discoveries, and the organic references in question remain only as an analogy of form that can be traced in architectural structure, far from function. This method of emulation, which began in antiquity, seems to have taken its place in today's deconstructivist conditions.

Architect Maibritt Pedersen Zari, who carried out a comparative analysis of the existing literature on biomimetic possibilities, stated that the concept of biomimicry can be interpreted on two levels. The first is called 'design in search of biology (top-down approach)' and includes the stage of examining the ability of other organisms to solve these needs as a result of defining human needs (Zari, 2007, p. 33). This design approach, which describes the process of designers looking at the living world for possible answers to problems and then creating solutions by referring to organisms that have solved similar problems, appears as one of the conditions for designers to determine their goals (Aziz & El sherif, 2016, p. 708). The design process of the bionic vehicle, the prototype of which was designed by the German car manufacturer DaimlerChrysler, is a vivid example of this approach. In this design, inspired by the Ostracion Meleagris, known as the boxfish, the aerodynamic structure of the fish guided the formal structure of the vehicle. By referring to the postural data obtained as a result of analysing the shape of the fish in the water and transferring it to the digital environment, 40% more strength was achieved in the computerised designs of the vehicle produced.

The second approach is called 'Biology Influencing Design (Bottom-up Approach)' and refers to making a defined characteristic behaviour or function found in the ecosystem available in the design. This approach, which describes the identification of the behaviour of an ecosystem or organic reference and the use of the identified characteristics to respond to a specific need, requires designers and biologists to work together (Zari, 2007, p. 33). The working principle of the exterior paint called Lotusan, produced by the London-based insulation brand Sto, is a qualified example of this approach. Inspired by the nelumbo, also known as the lotus flower in the literature, the chemical structure of the paint is based on the static repellent properties of the flower. The lotus leaf, which has hydrophobic (water-repellent) properties due to the thin wax secretion covering its surface, is considered to be one of the materials with the most specific waterproofing properties in nature (Gruber, 2011, p. 51).

As can be seen from the literature, the interrelated relationship between nature and man has had a direct impact on design processes. As a result of this interaction, the connection between nature and design has not only been a source of formal inspiration but has also contributed to the design disciplines with the systems it contains. Volstad and Boks (2012, p. 190) classify the categories of biomimicry that contribute to design processes into four basic groups: material, space, structure and form. In design, concepts from the science of biology, such as mutation, morphogenesis, fluidity, continuity and collective movement, have enabled architecture to take on the complex but dynamic forms of natural systems. Thus, architecture has been transformed from a static and lifeless object into a dynamic and integrated structure with the environment. It is in the context of this transformation that the following part of the research addresses the relationship between biomimicry and the discipline of architecture.

2.2. Biomimicry in Architecture

Nature contains adaptive capacity in the form and function of the physical environment. This capacity, which can be seen in all ecological systems from simple unicellular structures to complex multicellular organisms, includes systems that can be exploited at the architectural scale. In this vein, biological approaches in architecture should be taken beyond formal concerns and incorporate parameters like functionality and sustainability that nature offers. In this sense, the discipline of architecture, which makes use of organic references, should be able to transfer the orientations produced by nature to technical solutions and offer contemporary approaches to design, producing new criteria through the concept of space. However, the ambiguity created by the openness to possibilities of the biological references that contribute to the design disciplines and the static conditions of immutability offered by the accepted parameters both produce opposing ideas and create layers that can theoretically work together.

The discipline of architecture, by its very structure, also contains this opposition. In order to better understand the conditions under which the processes related to the experience of architectural design processes are programmed, which should be considered as an orientation on both intellectual and operational scales, it is necessary to clarify the approaches to the fundamental issues of biomimicry and the techniques related to the abstraction process. However, although designers have used biology as a source of inspiration for thousands of years, there is no normative process specific to biologically inspired design practice (Helms et al., 2009, p. 611). Therefore, it is expected that the proposed design searches will be defined by technical narratives produced in accordance with spatial boundaries, taking into account international trends in the inclusion of biology in design. In recent decades, there have been some extensive studies on the methodology of this approach to design. Research into the development of biomimetic systems is increasing in order to understand biological phenomena in detail and to develop technologies that mimic these phenomena (Elibol et al., 2021, p. 679).

In this vein, Helms et al. (2009, pp. 611-612) from the 'Design Intelligence Lab' at the 'Georgia Institute of Technology', which established the 'Centre for Biologically Inspired Design' to ensure the representation of biology at the architectural scale, defined biologically inspired design approaches with a six-tier structure: (1) problem definition; (2) reframe the problem; (3) biological solution search; (4) define the biological solution; (5) principle extraction; and (6) principle application. This six-tiered structure, aimed at preserving common behaviours and metabolic balances in natural environments, has also made it possible to create living environments that directly participate in organic design processes, that can react, evolve, self-organise and develop by adapting to their environment.

Lakhtakia and Martin-Palma, who examine design at three basic levels in the context of biological references, suggest that the primary approach is to compare a functional system with other organisms. This method, which evaluates how different organisms perform the same function, aims to provide more detailed information about functions and increase the diversity of solutions. It is recommended to study the model organism in isolation in the secondary approach. This method, which assesses current functioning rather than understanding the diversity of organisms, aims to develop an understanding of the system. The third and final approach is based on theory and modelling. This method, which attempts to discover dynamics in nature with virtual experiments, aims to mimic biological systems, test them under alternative conditions and improve designs with the data generated (Eryılmaz, 2015, p. 471).

Biomimicry, which is widely used in many design disciplines, especially in engineering and architecture, has found its place in all fields, from the simplest objects of daily use to the most complex architectural fictions involving human beings, and has paved the way for the production of many qualified designs. Contrary to the artificial structural fictions that shape today's understanding of design, the natural architectural fiction, which allows unlimited production of resources and efficient use of energy, also provides the necessary motivation for an ecological and sustainable living space that can evolve or organise itself, fed by organic references.

Within the concept of biomimicry, formal approaches produced by imitating natural events, flowering systems of plants and physiological qualities of living beings can find a response in the discipline of architecture as surface material, lighting, furniture, spatial envelope and building stock. Here it is possible for the organic reference to convey symbolic values, to be represented figuratively with a resemblance, or to evoke the functions of the product used to inspire. However, the spatial representations constructed through the use of biological systems in the processes of abstraction in question should not be limited to formal concerns, and these approaches, based on the production of ideas, should refer to the principles of formation, operation and survival of the organic concept to which they refer, both in terms of sustainability and functionality, and should move beyond being a mere visual imitation of nature.

The field of biomimicry, which recognises flora, fauna or whole ecosystems as a basis for design, has attracted worldwide interest in architecture and engineering. This is both because it is an inspiring source of possible new innovations and because of the potential it offers to create a more sustainable built environment. However, although various forms of bio-inspired design have been discussed by researchers in the field of sustainable architecture, the widespread and practical application of biomimicry as a design method has remained largely unrealised. In the discipline of architecture, biology is often used as a library of forms or decoration but imitating or being inspired by natural-looking forms, textures and colours is not in itself biomimetic. For a design to be truly biomimetic, it must be informed not only by the appearance of nature, but also by its biology (El-Zeiny, 2012, pp. 502-503). In this context, this paper develops a framework for the concept of 'morphogenetic design', which underpins the biological necessity for understanding different forms of biomimicry.

2.3. Morphogenetic Design Approach

Technology is rapidly changing physical environments and has a significant impact on modern design. During the first quarter of the 21st century, living spaces have become both receivers and transmitters of electronic information due to the continued flow of digital revolution. The need for flexible design constructs has led to the theoretical representation of mechanical systems on a universal scale. Mitchell (1996) evaluated the current conditions of the interaction between virtual reality and the concept of space. He predicts that in the near future, dwellings will become an indispensable part of users, like organs or nervous systems.

In contemporary architectural practice, some researchers and architects are utilising nature's internal systems and fundamental principles to construct a more sustainable and distinctive built environment. In these studies, the goal is not to simply imitate nature, but rather to understand the reasons behind the structural transformations of living organisms and to uncover the problems to which these transformations provide solutions in nature. In this context, computer-based technologies are used to design a product by determining all parameters and finding the most appropriate solution to the design problem. This approach enables designers to utilise straightforward descriptions of the principles of organism systems to address ecological concerns, such as enhancing mobility, creating new materials, providing natural air conditioning, and utilising solar energy. The architectural literature refers to these practices as ‘Morphogenetic Design’ or ‘Digital Morphogenesis’. They also define areas of research on the concept of sustainability.

The book 'Biomimetics in Architecture: Architecture of Life and Buildings', published by Petra Gruber in 2011, discusses inferences about the distinctive features of biological organizations. It suggests that an analogical relationship can be established between the vitality criteria, referred to as life criteria, and the discipline of architecture. Gruber (2011, p. 124) examines the criteria of life under eleven headings: openness, information, order, reproduction, growth, energy, reaction, homeostasis, evolution, self-organization, and limitation. The author compares the life cycle of architecture with the natural processes of organisms. Morphogenetic design combines the Greek words 'morph', meaning change of form, and 'genesis', meaning creation. It expresses the development of an organism on a formal scale and intersects with a contemporary understanding of architecture. An organism can only differentiate as much as the possibilities offered by its genetic realities. The evolutionary design ideologies expressed in the book 'An Evolutionary Architecture', published by John Frazer in 1995, in which the basic form processes produced from ecological morphogenetic theories are examined at the architectural scale, directly refer to morphogenetic design approaches in terms of the metamorphosis of organisms.

3. Morphogenetic Design Through Hypothetical Housing Examples

Building on the theoretical framework discussed above, this section introduces four speculative housing projects—Embryological House, Multistory Apartment, Molecular Engineered House, and Fab Tree Hab—as conceptual case studies to explore how morphogenetic design approaches manifest within residential architecture. These examples serve as analytical tools to examine the generative principles, material strategies, and ecological logics embedded in morphogenetic thinking.

3.1. Embryological House

Greg Lynn's Embryological House project proposes six parent housing prototypes with different genetic algorithms, exploring the communication between morphogenetic design approaches and the concept of organic algorithms at the architectural interface. These carrier housing models have different geometric identities despite sharing similar constructional features. They can create numerous living spaces that respond to the biological demands of the natural physical environment (Lynn, 1999, pp. 19-20). This is a digital simulation of embryonic development processes realised through computer-generated algorithms. It is also considered a spatial production control in terms of the diversity and continuity it offers to the user. The morphology of the embryo has been interpreted allegorically, allowing for the examination of embryonic design processes in architecture. The housing prototypes' plan scheme matches the circle form in terms of topological characteristics. It is controlled by 12 parametric reference points, which allow the formation of prime geometric forms (Figure 1).

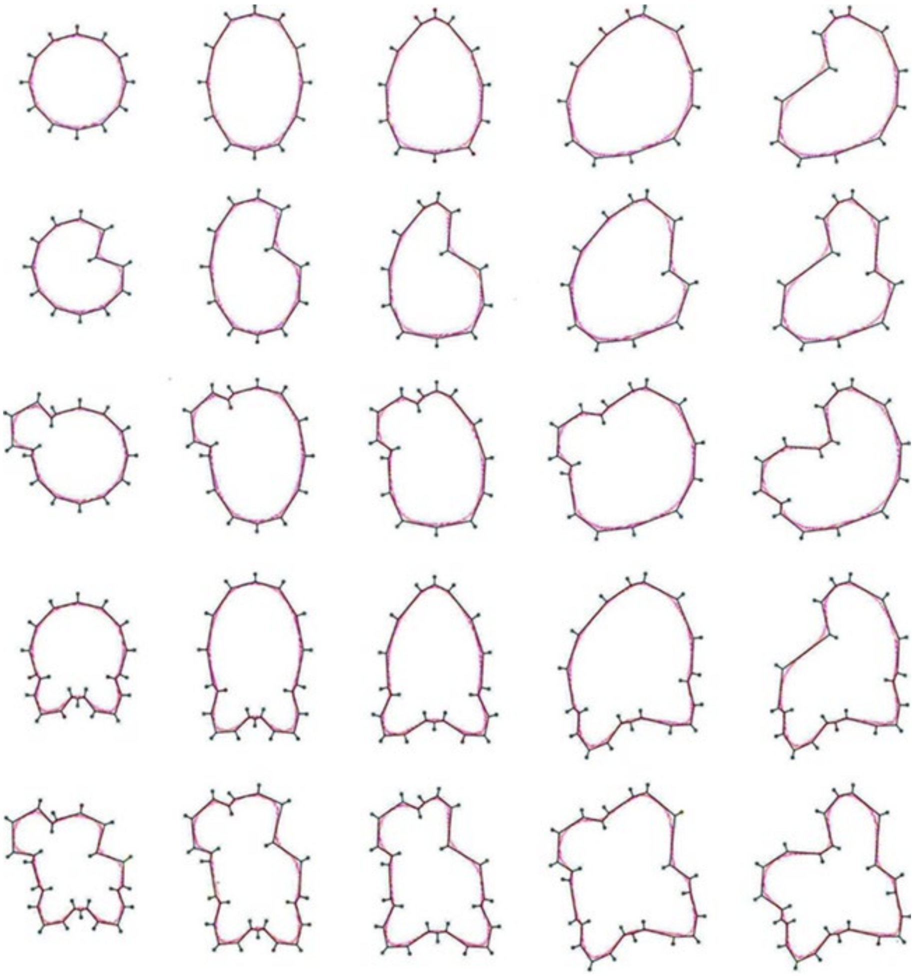


Figure 1 Embryological house - Generative plans (Keller, 2012)

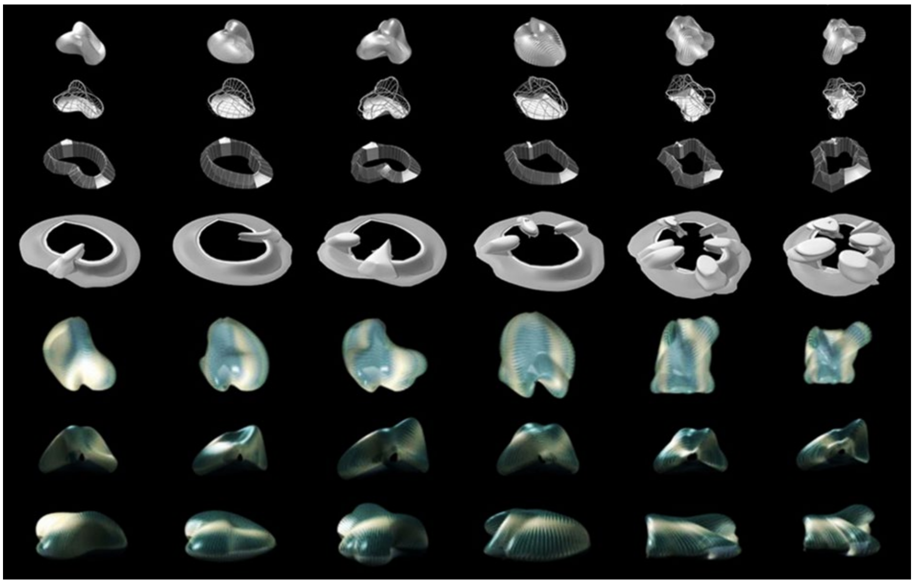


Figure 2 Embryological house - Prototype process (Keller, 2012)

The Embryological Housing project explores the concept of variation through architecture and the geometric limits of diversity at the scale of space. By following a standardised production procedure for each dwelling, this project is able to create numerous geometric iterations while maintaining a set of common parameters. This approach enables the production of optimal forms. Variations of the embryological house can be adapted to suit the user's living conditions, needs, or aesthetic preferences. This parametric variation, also known as mutation, ensures that each housing prototype is both unique in form and function (Figure 3).

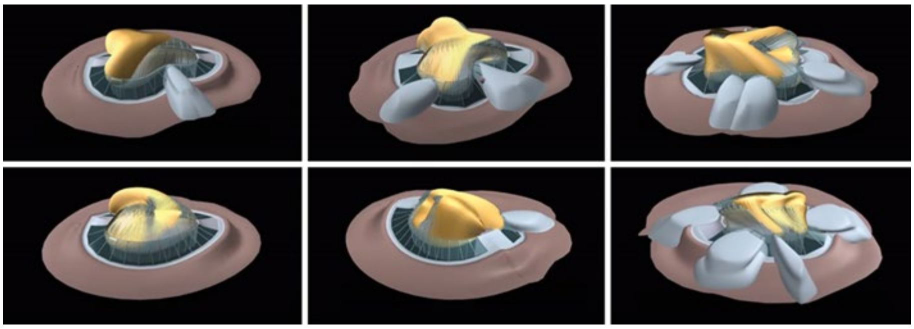


Figure 3 Embryological house - Prototype perspectives (Glform, 2008)

The construction of the Embryological house, which is layered with the help of a vertically moving structure and surrounded by a double-walled shell, is supported by panels connected to circular steel beams. The initial layer comprises semi-permeable glass panels attached to aluminium profiles. This layer serves two purposes: to allow natural light into the space and to create a visual connection with the surrounding environment. The second shell can respond to the intensity of daylight with the help of computer-generated algorithms. It can also cast shadows on the first layer when necessary, allowing for the control of natural lighting conditions. This communication between the shells of the house not only reduces the lighting and heating costs of the building, but also proposes an approach that represents efficient energy use on a sustainability scale (Lynn, 2000, p. 28). The spatial fittings in the embryonic house are designed with reference to a movement that can realise the stages of change and development of an embryo within its own structure. In this context, the sleeping environments, seating areas, and storage elements are not considered as individual pieces of furniture, but rather as multifunctional environments with dynamic characteristics (Figure 4).

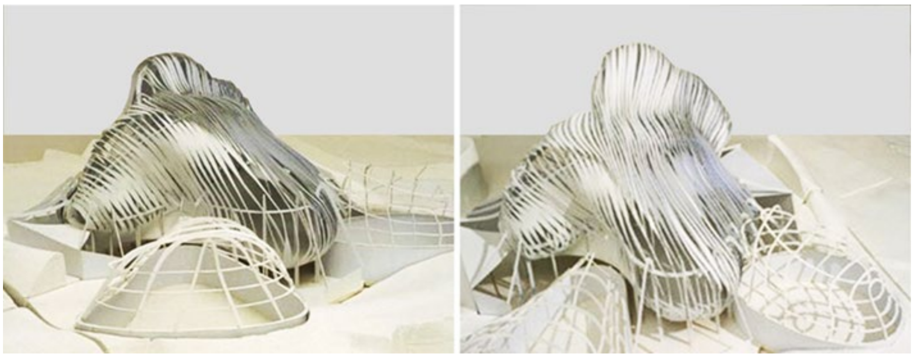


Figure 4 Embryological house - Prototype (CCA, n.d.)

The morphogenetic design approach shares the same theoretical foundation as the evolutionary design ideas proposed by John Frazer, in terms of the metamorphosis of organisms. This understanding, interpreted as an imitation of evolutionary processes carried out with the help of genetic algorithms produced in a computer environment, has also contributed to the modeling of a design process similar to the modern evolutionary synthesis concept of Neo-Darwinism. Suggesting that there are flaws in the design process of CAD programs, which can only work within limited patterns and are inadequate to create original forms, Frazer proposes that instead of constructing a new system based on commands, a digital model should be fed by genetic parameters and be able to make inferences on its own (Frazer, 1995, pp. 20-26). Frazer, who developed a design process for the production of forms that could grow or organize themselves in a manner similar to the evolutionary process in nature, enabled the processing of information as in the DNA chain and the production of unpredictable complex forms with the help of a computer technology in which biological change is expressed numerically with hereditary algorithms.

3.2. Multistory Apartment Building

The Multistory Apartment Building project by J. M. Johansen presents a mass housing proposal that shares the same processes as Molecular Designed Housing in terms of growth strategy but needs to be controlled by more obscure genetic information and demonstrates that morphogenetic design approaches can be used as a production method even in multi-storey buildings (Figure 5).

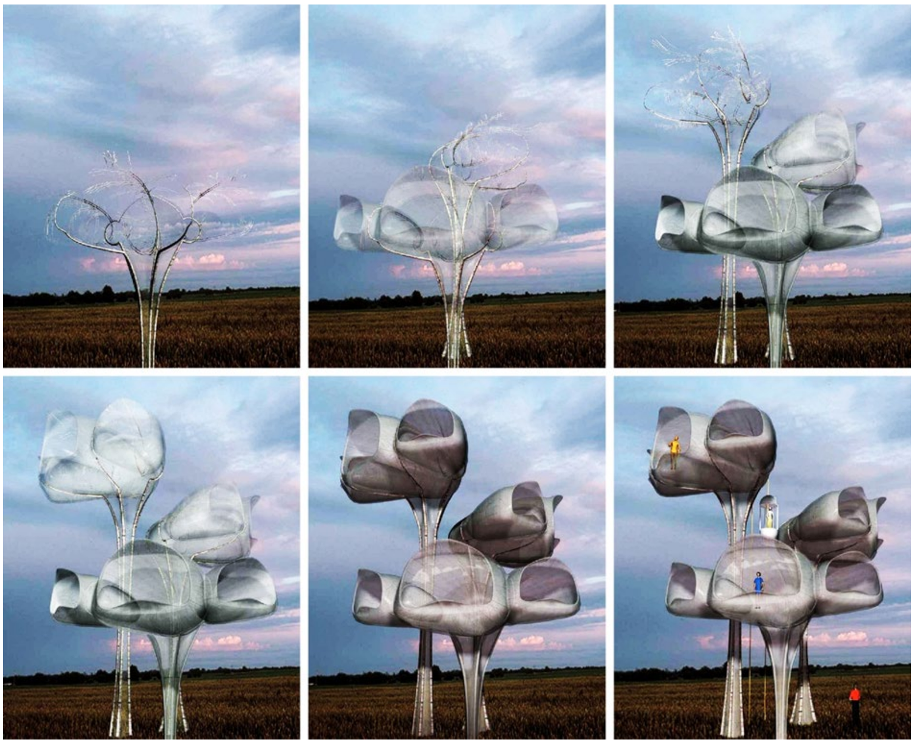


Figure 5 Multistory apartment building - Organic growth process (Johansen, 2002)

This housing proposal, in which J. M. Johansen's ecological concerns intersect with morphogenetic design processes, preserves all the genetic parameters necessary for repair requirements in its seed. Using homeostatic mechanisms to maintain its metabolic balance, the building also responds to the desires and needs of the user within the possibilities of its natural physical environment. The design, which senses and adapts to changing terrain and climate conditions, can also produce its own energy. This biologically generative design interprets and organises all its structural reinforcements according to the differences in humidity, heat and light, and aims to optimise the total amount of energy used in the production of the installations that control these parameters.

3.3. Molecular Engineered House

The Molecular Engineered House project developed by J. M. Johansen for the year 2200 refers to evolutionary design principles. The project, which is based on the principle of organising the designer's structural ideas in the computer environment using algorithms and encoding all the resulting genetic information in a seed and planting it in the ground, develops like a plant after a nine-day evolutionary process (Johansen, 2002, p. 133) (Figure 6). In order to create new living spaces, the design of the house, which can be expanded and subdivided, takes into account the physical needs of the users and can, if necessary, extend its formal limits in order to provide answers to these needs. This ecological structure, fed by morphogenetic algorithms and behaving like a living organism, can also reason for itself and take evolutionary decisions based on environmental conditions.

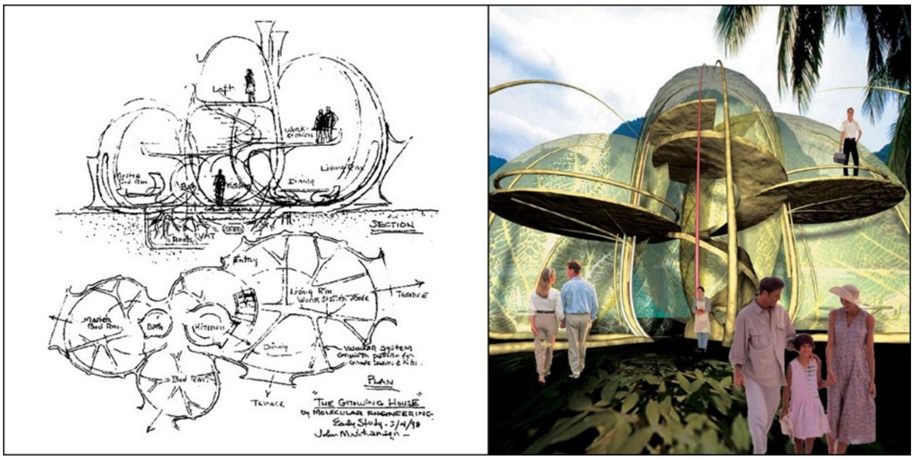


Figure 6 Molecular engineered house (Johansen, 2002)

As a morphogenetic fictional proposal, the roots that form the basis of the Molecular Designed Housing form the truss system, vertical spines, platforms (floors), walls and openings respectively. In this context, the house, which can renew its form, organisation and material density according to the conditions in which it finds itself, can also respond to the needs of its users. This open system design, which is self-sufficient, independent of public services and able to exchange materials with its immediate surroundings, contains the materials needed for repair processes in its core and maintains its spatial conditions in balance thanks to its homeostasis mechanism against physical effects. The membrane layer, which completes its development at the end of the eighth day, both communicates with the natural environment through its permeability and assists the structure in directing daylight into the space. This organic envelope proposal, which reduces the building's lighting and heating loads, also offers a system proposal in terms of efficient energy use (Figure 7).

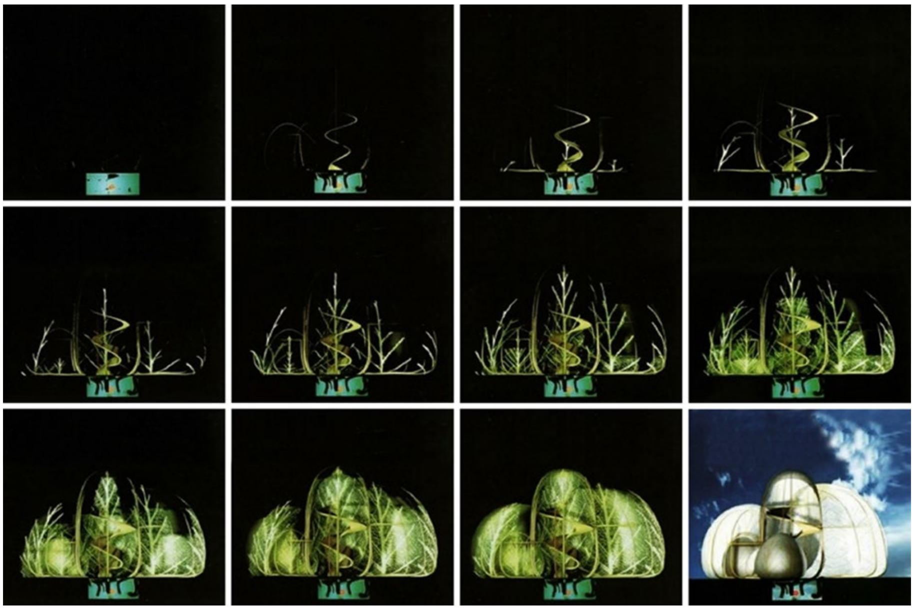


Figure 7 Molecular engineered house - Organic growth process (Johansen, 2002)

The design proposal, which aims to preserve the common behaviour and metabolic balance of the natural environment, participates directly in the organic design process and acts like an organism. In this respect, the molecular dwelling, which can react, evolve, self-organise and develop by adapting to its environment, both adapts its construction to seasonal conditions (light, temperature, humidity, etc.) and minimises the total amount of energy and material costs spent on the production of building stock.

3.4. Fab Tree Hab House

The Fab Tree Hab House, developed in 2003 by Javier Arbona, Mitchell Joachim and Lara Greden, is a hypothetical ecological housing project. It aims to articulate the idea of lightening the burden of humanity by growing living and breathing tree houses with traditional housing in an ecological environment. The idea aims to replace the old solutions produced by Habitat for Humanity International and proposes an alternative method of growing houses from endemic trees. The organic reference is formed on a computer-generated prefabricated structure, and the resulting envelope integrates the dwellings into a sustainable physical environment and ecological organisation (Figure 8).

Figure 8 Fab tree hab - Organic growth process (Arbona et al., 2003)

Rejecting traditional anthropocentric doctrines and composed entirely of nutrients, Fab Tree aims to adapt the user directly to the terrestrial environment. In this context, the indeterminate housing also adapts to the surrounding ecosystem in a symbiotic way (Arbona et al., 2003, p. 48). The project, developed with pleaching systems, incorporates a contemporary methodology for the discipline of architecture, even if it is traditional for landscape approaches, and enables the production of sustainable natural systems by exploiting morphogenetic possibilities at the molecular level. In this respect, Fab Tree, which is directly involved in the organic design process, proposes a sustainable housing model that is organised, adapts to the metabolic balance, and allows efficient energy use.

Figure 9 Fab tree hab - Prototype perspectives (Arbona et al., 2003)

4. Methods

4.1. Model

This study adopts a qualitative research design based on a general inductive approach. Rather than testing hypotheses, this approach seeks to build understanding through the interpretation of data within its natural context. The aim is to explore how morphogenetic design approaches relate to housing production by generating insights grounded in theory and conceptual reasoning. In this framework, the researcher interprets selected examples not to validate predetermined claims, but to construct a reflective understanding based on emerging patterns and thematic associations.

4.2. Sample

The research sample consists of four hypothetical housing projects: Embryological House, Multistory Apartment Building, Molecular Engineered House, and The Fab Tree Hab. These projects were developed using morphogenetic design approaches after the year 2000. These projects were selected through purposeful sampling, specifically homogeneous sampling, as they collectively provide a coherent foundation for conducting a comparative analysis within a shared conceptual domain. The selected examples represent distinct approaches to morphogenetic design within residential architecture. Each project reflects a different interpretation of form generation, material strategy, ecological responsiveness, or biological integration. Despite their diversity, they share a common speculative character and were all conceived within a theoretical or conceptual framework rather than as conventional construction proposals. This makes them particularly suitable for comparative theoretical analysis.

4.3. Data Collection Tools

A comprehensive literature review was conducted to examine the theoretical background and limitations of morphogenetic design approaches in the context of housing production. This process involved identifying, analyzing, segmenting, and synthesizing relevant academic sources to construct the conceptual framework of the study. In addition to secondary sources, primary materials written by the designers of the selected projects were also utilized, including research articles, project reports, and conceptual texts. Both printed publications and digital resources such as articles, theses, and project documents accessed online were used in this context.

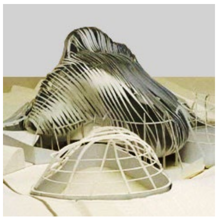
4.4. Data Analysis

The data were analyzed in two stages using descriptive content analysis, with the aim of clarifying the research problem and contributing to the development of a conceptual framework. In the first stage, a descriptive analysis was conducted to identify general patterns and thematic tendencies in qualitative studies related to morphogenetic design and housing. In the second stage, content analysis was applied to the selected hypothetical housing projects. The data were categorized and interpreted based on a set of parameters defined by the researcher in alignment with the study's theoretical framework. These parameters emerged from recurring conceptual themes identified during the literature review on morphogenetic design. Aspects such as generative form logic, material organization, spatial configuration, sustainability emphasis, and the use of biological metaphors appeared as common strategies across both the literature and the selected examples. These themes were then adapted as analytical categories to support a coherent comparison of the case studies.

5. Findings and Discussion

In the context of the study aimed at understanding the impact of morphogenetic design approaches on housing production processes, the literature review method was preferred to seek answers to the research questions. The data obtained from the research was subjected to a descriptive content analysis, and the resulting findings – organised by key parameters and thematic categories – are systematically presented in Table 1.

Table 1 Comparison of Hypothetical Housing Samples

	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
	Embryological House (2000)	**Multistory Apartment Building (2001)**	**Molecular Engineered House (2002)**	**The Fab Tree Hab House (2003)**
Parameters				
Designer	G. Lynn	J. M. Johansen	J. M. Johansen	J. Arbona et al.
Institution	UCLA	FAIA	FAIA	MIT

Generation time	unknown	unknown	nine days	five years
Procedure	self-determination	self-development	self-selection	natural selection
Structure	steel construction	none	none	plywood scaffold
Variation	very-high	high	high	fair
Homeostasis	high	high	very-high	very-high
Feasibility	very-low	low	fair	high
Symbiotic relations	fair	high	high	very-high
Human interference	low	fair	high	very-high
Sustainable energy	high	high	high	very-high

The diversity in institutional affiliations and professional identities across the selected housing projects reflects the cross-disciplinary origins of morphogenetic design thinking. This variation suggests that morphogenetic design is less a singular architectural style and more a framework for hybrid research and production practices, often shaped by the epistemologies of the institutions or fields in which they are developed. The hypothetical housing examples developed by diverse institutional affiliations (e.g., UCLA, FAIA, MIT) and professional titles (e.g., architect, academic, researcher) illustrate that morphogenetic design is not merely an 'architectural innovation' but also a 'research-production' model grounded in interdisciplinary collaboration. The involvement of experts from related fields, including building biology, ecology, computational design and materials science, within the same project, reinforces both design continuity and innovation (Picon, 2010). Consequently, it can be inferred that the concept of 'housing' will evolve into more flexible, multi-layered, and adaptive systems through the interaction of various fields of expertise in the future.

The disparity in 'generation time' among the projects reveals how morphogenetic thinking encompasses both computational speed and biological duration. The iterative short-cycle process seen in digitally driven projects contrasts with the slow-growth logic of biologically integrated designs, signaling two distinct temporalities in architectural speculation. This temporal duality is further explored in the literature, as advanced digital frameworks have enabled projects to generate new variations in an iterative and rapid manner, thereby undergoing numerous design cycles within a short period. By contrast, projects utilising natural/biological materials require a longer timeframe for the growth and environmental adaptation of plant- or living tissue-based building elements. This approach is consistent with Armstrong's (2015) theoretical framework of 'vibrant architecture', which aims to integrate buildings with organic systems as a transformative agent in ecological processes. In this context, the 'generation time' parameter in the hypothetical housing examples varies across all stages of design, construction, and sustainability.

The classification of procedural logics across the projects demonstrates a spectrum of design agency, ranging from designer-led authorship to autonomous, nature-influenced processes. These procedural terms serve not just as technical labels but as indicators of philosophical orientation in design methodology. This conceptual nuance is also articulated in the theoretical literature, where DeLanda (2013) associates the perception of design as an iterative and multiparametric process with approaches that liken architecture to the evolutionary development of living organisms or biological forms. In this context, the expressions 'self-determination,' 'self-development,' 'self-selection,' and 'natural selection,' found under the 'procedure' parameter in the hypothetical housing examples, also correspond to the 'evolutionary' or 'organic' line of thinking that underlies morphogenetic design. Consequently, it can be asserted that each project represents its own unique algorithmic principles, ranging from those involving user scenarios to those relying almost entirely on automation, in generating its design methodologies.

The contrasting structural approaches observed in these cases reflect not just material or formal variety but conceptual repositioning of tectonic logic. In some examples, the 'structure' becomes an emergent property rather than a pre-defined system. This perspective is further supported by architectural research. It has been posited by researchers such as Hensel et al. (2010) that bio-inspired structural models have the potential to establish the foundations for adaptive, lightweight, and low-energy housing in the future. In this context, the various approaches – such as 'steel construction' and 'plywood scaffold' – listed under the 'structure' parameter offer insights not only into the external form shaped by morphogenetic design but also into the extent to which a building can be assembled in an 'organic' manner. Furthermore, the seemingly 'completely structureless' approaches proposed by architects like Johansen suggest that structural elements may either be dispensed with in the traditional sense or arranged in fundamentally different configurations.

The emphasis on high homeostasis, symbiotic relations, and sustainable energy suggests an underlying aim to simulate or participate in ecological systems. These values point to morphogenetic architecture's ambition to function not only as form but as environmental agent. This alignment between conceptual intent and design outcome is reflected in the literature, where the data obtained under the 'Homeostasis', 'Symbiotic relations' and 'Sustainable energy' parameters reflect the degree of ecological sensitivity in the hypothetical housing examples. In particular, the fact that 'The Fab Tree Hab' addresses sustainable energy at a 'very-high' level suggests that the structure is conceived as a 'living' system capable of directly supporting ecological cycles. This approach is analogous to Reiser and Umemoto's (2006) concept of 'architecture embedded in the ecosystem'. However, while sustainability is emphasised in these examples, their low or limited feasibility indicates that these concepts remain at an experimental stage and highlights the challenges of integrating them into conventional construction practices.

The inverse relationship between variation and user interference observed in certain cases raises critical questions about authorship and participation. High morphological complexity generated by autonomous systems may come at the cost of end-user agency in design outcomes. These tensions are similarly acknowledged in scholarly discourse, as the observed discrepancies in the 'Variation' and 'Human interference' parameters necessitate a consideration of the extent to which users can be active in housing design, as well as the degree to which the building's inherent "systematics" may exert a determining influence. For instance, combining 'very-high variation' with 'low human interference' suggests that the designer's or the algorithm's initiative is dominant. This scenario brings to mind the existing literature that interrogates the relationship between digital design technologies and users. The more algorithmically the building's form, spatial organization, and even material choices are determined, the more user flexibility and participation may be constrained or redefined (Kolarevic & Malkawi, 2005).

The analysis indicates that morphogenetic design has the capacity to substantially transform the formal, functional and ecological dimensions of future residential buildings (RQ1). Digital design methods, biologically inspired production techniques and user-participatory design strategies have rendered it feasible for buildings to self-renew, establish symbiotic relationships with their environment and adapt to various living scenarios. This process is characterised by the integration of sustainability and user experience across multiple stages, ranging from design to construction (RQ2). Consequently, architects, engineers, and users interact within a continuous feedback mechanism, exploring pathways to produce housing solutions that are more responsive to both technological and environmental demands.

However, all the projects included in this analysis were evaluated only on the basis of the scientific documents published by the designers. Of course, it is possible that all the projects presented here serve different purposes in different contexts and can therefore be evaluated on the basis of different parameters. This analysis should therefore be regarded as rudimentary and in need of improvement.

6. Conclusion

The concept of morphogenetic design is one of the driving forces behind modern design orientations shaped by the constantly changing and evolving rules of nature. In this context, it is essential to observe the measurements, behaviors, and structural transformations that nature undergoes when confronted with physical challenges. The data obtained from such observations must be critically interpreted and translated into architectural strategies, and the generation of solutions that can be integrated into design stages contributes to the advancement of morphogenetic thinking.

This study highlights that morphogenetic design is not merely a response to material and environmental constraints, but a paradigm that redefines the ontological status of form in architecture—shifting it from an object to a processual, systemic construct. This refers to evolutionary perspectives in architecture. Morphogenetic design does not aim to change production techniques in architecture but instead seeks to transform design concepts themselves. It brings new identities to architecture in professional practice and allows for the reinterpretation of residential buildings on an organic scale. These innovations shape today's understanding of design and necessitate the articulation of current architectural discourses with morphogenetic paradigms.

In this context, morphogenetic design, which has developed its own terminology through its early examples, is defined as a new field that encourages collaboration between biology, engineering, and architecture through computer-based technologies. The morphogenetic design approach aims to solve design problems by referencing continuous systems observed in nature. It strives to create physical environments that are responsive to their surroundings and behave as living systems with all their components. This approach integrates concepts from various disciplines—such as genetics, coding, algorithms, and parameters—into the architectural profession through advancing technology. Morphogenetic design is gaining increasing recognition in both architectural literature and practice through the experimental works of designers such as Greg Lynn, John Frazer, M. Johansen, Mitchell Joachim, Javier Arbona, Lara Greden, Steffen Reichert, Achim Menges, and Angelica Lorenzi.

By using speculative housing examples as conceptual testbeds, this study investigates how designers transform spatial exploration into ecological organization through algorithmic processes. In doing so, it proposes an alternative model of architectural inquiry—one that integrates ecological reasoning with computational form generation within the experimental framework offered by residential design. Based on the comparative analysis in this study, it can be asserted that morphogenetic design does not merely function as a conceptual ideal, but actively generates alternative logics for material organization, spatial variability, and environmental responsiveness within residential architecture. Unlike purely descriptive studies, this research provides an integrated reading of how design concepts such as variation, structure, homeostasis, and generative logic are operationalized across different projects. Thus, it offers an original contribution by bridging the gap between conceptual theory and speculative application in architectural research. Furthermore, the research underscores how morphogenetic frameworks may inform future design education and practice by modeling alternative workflows that integrate generative systems and environmental parameters from the earliest design stages.

As a result, the study consolidates and extends morphogenetic discourse by articulating how ecological principles are operationalized through speculative design scenarios in architecture. It provides critical insight into the evolving relationship between digital technologies, ecological intelligence, and architectural form-making. In doing so, the study positions morphogenetic thinking not only as a theoretical discourse but as a practice-oriented paradigm that has the potential to reshape residential architecture.

However, a significant methodological limitation of this study is that the data were collected solely from four projects developed after the year 2000. The limited sample size reduces the generalizability of the findings and negatively impacts the external validity of the study. Therefore, it can be concluded that the analyses provided are explanatory rather than evidential. To improve external validity and enable the generalization of the data, it is recommended that future studies include a wider range of architectural cases developed using morphogenetic design approaches. Moreover, the advantages and limitations of morphogenetic design may not be fully understood without comparing them to conventional architectural approaches. Comparative analyses are often useful in identifying the strengths and weaknesses of different design strategies and evaluating the results in a broader and more integrated context. This framework points to a promising future research direction: a comparative analysis of morphogenetic and conventional design models.

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Resume

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