METU JFA 2025/2
(42:2) *51-69*

DOI: 10.4305/METU.JFA.2025.2.3

# PROCESS VERSUS OBJECT: EVOLUTIONARY ARCHITECTURE THEORIES OF JOHN FRAZER AND EUGENE TSUI

**Melih KAMAOĞLU*, Demet YILMAZ YILDIRIM****

**Received:** 16.05.2024; **Final Text:** 26.08.2025

**Keywords:** Evolutionary architecture; philosophy of nature; evolution theory; computational design; architecture theory.

**1.** This article is derived from the master's thesis of Melih Kamaoğlu, entitled 'Evaluation of Evolutionary Architecture through the Relationship between Philosophy of Nature and Architecture,' completed in 2020 at the Department of Architecture, Karadeniz Technical University, under the supervision of Assoc. Prof. Dr. Demet Yılmaz Yıldırım.

* *Corresponding Author;* Department of Architecture, Karadeniz Technical University, Trabzon, TÜRKİYE.

** Department of Architecture, Karadeniz Technical University, Trabzon, TÜRKİYE.

## INTRODUCTION

The natural world has long served as a source of inspiration for human creativity and design. Throughout history, people have imitated natural forms, structures, materials, and systems in the environments they built. In architecture, this connection has evolved over time from simple early imitations to more complex design approaches shaped by changing views of the natural world. These shifting perspectives are closely tied to the philosophy of nature. Architecture offers a valuable lens for observing how such philosophical ideas have influenced the development of the built environment. From the inquiries of pre-Socratic philosophers about the essence of the world to the emergence of evolutionary theory, the philosophy of nature has played an important role in shaping architectural theory and practice (Kamaoğlu, 2020).

Philosopher and historian Robin George Collingwood categorized different conceptions of nature into three major historical periods: the Greek, the Renaissance, and the Modern era (Collingwood, 1945). In Ancient Greece, nature was understood as an organism, with order emerging from the presence of mind or intelligence. During the Renaissance, nature was viewed as a machine, with its order structured by divine design. In the Modern era, Collingwood identified the theory of evolution as a key transformative force in shaping how nature is understood, along with advances in modern physics and cosmology. According to Collingwood, these developments marked a significant paradigm shift, one that Charles Darwin helped to initiate through his theory of evolution (Darwin, 1859, 490).

Before Darwin, the prevailing view held that all living creatures were static, unchanging, and unalterable beings, each reflecting a certain degree of perfection within a fixed hierarchy of life (Futuyma and Kirkpatrick, 2023). With the introduction of evolutionary theory, nature came to be understood as a dynamic reality that is constantly changing, evolving, and developing over time (Huxley, 2010). After considerable debate among scientists, evolutionary theory became the central explanatory framework in biology (Dobzhansky, 1973). Over time, the mechanisms of evolution were increasingly clarified, from the genetic level to environmental influences, thanks to advances in genetics and ecological science (Gayon, 2016). Later, the simulation of natural evolution became feasible through developments in computational systems (Bentley, 1999; Holland, 1975). By the early 1990s, some architects began integrating evolutionary theory into design thinking and practices using computer technologies.

Over the past three decades, the use of evolutionary theory in architectural design has developed along two primary trajectories (Kamaoğlu, 2023b). The first focuses on simulating evolutionary processes through computational systems, while the second seeks to directly integrate material and biological processes into the design and production of architecture. In the first approach, architects use digital tools to abstract and model mechanisms such as mutation, selection, and adaptation, translating them into algorithmic procedures that generate and evolve architectural forms within virtual environments (Coyne, 2018; Holland, 2010; Steadman, 2008). This perspective treats computation and nature as separate domains, with design outcomes emerging from simulated processes inspired by biological evolution. The second approach moves beyond simulation by embedding biological, material, and environmental dynamics directly into the design process (Cogdell, 2018; Ireland, 2024). In this view, architecture is understood as an active system that interacts with its environment. Therefore, design processes are shaped by biological behavior and informed by principles such as material responsiveness, self-organization, and the integration of living systems.

Early experiments explored the potential of artificial evolution and cellular automata to generate architectural forms that change and develop over time (Frazer, 1995b). In later developments, theoretical models based on concepts like endosymbiosis and morphogenesis were introduced to examine continuous variation, formal transformation, and soft geometries in design (Lynn, 2000). This shift moved architectural focus away from fixed, object-based outcomes toward process-driven systems that evolve in response to multiple variables. In addition, evolutionary principles informed performance-based design strategies, where material behavior, environmental feedback, and systemic responsiveness were incorporated to shape adaptive and multifunctional architectural solutions (Hensel et al., 2004). However, the application of evolutionary processes and principles in these approaches remained confined to the boundaries of the digital environment.

More recent strategies have aimed to bridge the gap between computational systems and the physical world by engaging directly with biological and material processes. These models emphasize the use of bio-integrated and bio-receptive materials to enable interaction between architecture and its environmental context (Cruz and Beckett, 2016). Living organisms, microbial systems, and responsive materials are treated as active components in the design process, contributing to form generation, adaptation, and transformation over time (Dade-Robertson, 2020). Biological phenomena such as colonization, growth, and environmental sensitivity are not merely represented but incorporated into the physical development of architectural systems through computational monitoring and design control (Ruth et al., 2023). This approach reframes the built environment as an adaptive interface, where computational design, material behavior, and biological processes are closely interwoven.

These two directions reflect fundamentally different ways of engaging with evolution in architectural design. The first treats evolution as a process, focusing on its underlying mechanisms such as mutation, variation, and selection, and seeks to translate these into computational methods and algorithmic design strategies. The second understands evolution as an outcome, drawing from the formal, structural, and organizational results produced by natural evolutionary development to inform architectural thinking. Both perspectives began to take shape in the early 1990s, marking a pivotal moment in architectural theory. Rather than surveying a broad set of examples from this period, the following analysis focuses on two foundational cases: John Frazer and Eugene Tsui. Their work captures the initial spark that sets evolutionary thinking in architecture on two distinct paths, shaping much of the discourse that would unfold in the decades that followed.

Frazer employed a bottom-up design strategy, using digital computation to simulate evolutionary and morphogenetic processes in order to generate architectural forms (Frazer, 1995b). His work focused on the mechanisms of mutation, variation, and selection, treating evolution as a dynamic process that could be translated into algorithms and computational experiments (Kamaoğlu, 2023a). On the other hand, Tsui followed a top-down approach by analyzing the formal, structural, and material intelligence embedded in biological organisms as a result of millions of years of natural evolution (Tsui, 1999). Rather than simulating evolutionary mechanisms, he aimed to transfer the outcomes of natural evolution such as efficient structures, optimized materials, and ecological principles into architectural solutions (Kamaoğlu, 2021). In this way, Frazer and Tsui exemplify two fundamental and contrasting approaches to incorporating evolutionary theory into architectural design: one oriented toward process, the other toward outcome.

This article (**1**) highlights the importance of the philosophy of nature in architectural design by comparing the process-oriented and object-oriented evolutionary architecture theories of John Frazer and Eugene Tsui, particularly in relation to their approaches to evolutionary theory and design methodologies (Kamaoğlu, 2020). The aim is to illustrate the paradigm shift introduced by evolutionary theory in shaping the relationship between nature and architecture, and to demonstrate how this shift has led to two distinct design perspectives. The original contribution of this article lies in showing how evolutionary theory in biology paved the way for divergent architectural rationales, one emphasizing process and the other emphasizing outcome. Revisiting their work today is especially relevant because it allows us to trace the origins of two major trajectories in architectural thought. Understanding these early foundations offers critical insight into how architects continue to engage with questions of adaptability, complexity, and ecological integration in both digital and material contexts. Their relevance today lies in how they prefigure many of the concerns currently shaping the discipline, including the use of algorithmic design, the integration of living systems, and the search for ecologically adaptive forms.

The following chapters will begin with a concise overview of the relationship between the philosophy of nature and architecture prior to the emergence of evolutionary theory, emphasizing the key shift introduced by evolutionary thinking. This will be followed by a brief outline of the theoretical foundations of evolutionary architecture, focusing on its connections to biology, genetics, and computation. The main focus of the article will then turn to the contrasting approaches of John Frazer and Eugene Tsui, presented as early and foundational examples of process-based and object-based interpretations of evolutionary theory in architectural design.

## PHILOSOPHY OF NATURE AND ARCHITECTURE BEFORE EVOLUTION THEORY

The relationship between the philosophy of nature and architecture can be traced back to Ancient Greece. During this period, philosophers began seeking explanations for natural phenomena in observable mechanisms and processes rather than in metaphysical or supernatural causes (Russell, 2004). This shift encouraged reasoning grounded in physical reality and led to the perception of an intelligent order that extended from human beings to the larger cosmos. In this framework, harmony was seen as existing between the microcosm and the universe as a whole (Collingwood, 1945). This conception of nature found expression in architectural design through the use of order, harmonic ratios, symmetry, basic geometric forms, and the pursuit of perfection (Vitruvius, 1914).

In Ancient Greece, the arrangement of space on Earth was believed to reflect the cosmic order of the universe (Doxiadis, 1972). Pythagoras' view that nature operates through geometric formations and mathematical principles was evident in the use of primary geometric forms in architectural design. Plato's theory of forms inspired the pursuit of idealized shapes in building, while Aristotle's emphasis on purpose and completeness in nature encouraged architects to seek perfection in both design and craftsmanship. A prominent example is the Parthenon, which embodies the Greek conception of the universe by demonstrating how the ideal can be realized through human activity guided by reason (Roth, 2018). In this context, architectural design was seen as a manifestation of the perfection believed to lie at the heart of nature.

During the Renaissance, nature came to be studied not through teleological explanations but through emerging scientific principles that emphasized measurable and quantitative observation (Molland, 1993). With the rise of pre-modern science, nature was increasingly understood as a machine composed of parts designed for specific functions, governed by divine order but operating independently of metaphysical causes (Collingwood, 1945). Philosophers of the period embraced the idea that humans are the measure of all things, and that the universe could be explained by asking how phenomena occur, rather than why (Allsopp, 1959; Deming, 2014). These intellectual shifts laid the groundwork for the development of scientific thought, which would reach its full expression in the Enlightenment.

Renaissance architects regarded architecture as a discipline grounded in mathematics and rational order (Wittkower, 1988). They applied the rules of perspective as a scientific method for analyzing universal space and believed that ideal proportions could be achieved by combining primary geometric forms (Roth, 2018). The renewed study of Vitruvius's *De Architectura* played a central role in shaping an architectural language focused on symmetry, formal order, and geometric clarity (Ching et al., 2017). Within this framework, well-designed buildings were expected to mirror the proportions of the human body, with each part arranged in harmonious relation to the whole (Anderson, 2013). A notable example is Palazzo Rucellai, which illustrates this philosophy through its spatial organization based on geometric form and proportional balance.

During the Age of Enlightenment, philosophers and early scientists continued to seek the underlying principles of natural phenomena, aiming to develop a worldview grounded in scientific knowledge (Cevizci, 2018). Nature was increasingly understood as a machine operating through mechanical principles and governed by rational order (Collingwood, 1945). Physical laws, quantitative analysis, and mathematics became the primary tools for explaining natural complexity (Gaukroger, 2002). The rise of experimental science was driven by the principles of empiricism, inductive reasoning, and the need for repeatable results (Deming, 2014). A new conception of the philosophy of nature emerged, one based on scientific reasoning, objective inquiry, and the rational capacity of the human mind.

This rational understanding of nature was reflected in architecture through a design language based on basic geometric forms, simplicity in detail, functionality, and clear structural principles (Roth, 2018). Some architects looked to the rustic past or to the architectural traditions of Ancient Greece and Rome, while others embraced these ideas directly as expressions of rational thinking. Marc-Antoine Laugier argued that architectural arrangements should be functional and express a primitive classical purity, symbolizing a return to human origins and the rustic hut (Watkin, 2005). Neoclassical architects viewed the architecture of Ancient Greece and Rome as the purest and most unspoiled expression of design, favoring composition based on simple rules and proportions (Jordan, 1984). The Church of Saint Geneviève exemplifies this vision through its symmetrical design, use of primary geometric forms, and clearly articulated structural organization.

Before the introduction of evolutionary theory, the relationship between the philosophy of nature and architecture was grounded in a static worldview. The emergence of evolutionary theory disrupted this perspective by introducing a dynamic view of nature defined by variation, adaptation, and continuous transformation. Evolution challenged the idea of fixed natural laws and proposed that form and structure emerge through processes of change and interaction. In the early 1990s, advances in computation and genetics gave architects the tools to explore these processes in design practice. Before examining the contrasting approaches of John Frazer and Eugene Tsui, it is necessary to outline the theoretical foundations that support this field, particularly those drawn from biology, genetics, and computation.

## THEORETICAL FOUNDATIONS OF EVOLUTIONARY ARCHITECTURE: EVOLUTION, COMPUTATION AND GENETICS

The theoretical foundations of evolutionary architecture are rooted in three interconnected domains: evolutionary theory, genetics, and computational systems. The first major influence was the emergence of evolution theory, which fundamentally altered how nature and transformation were understood. This was followed by advancements in genetics, which provided a deeper understanding of how variation and inheritance operate at biological levels. Finally, the rise of computational systems offered the tools necessary to simulate these evolutionary processes within design environments. These three domains should not be considered in isolation. Without the explanatory power of genetics and the modeling capabilities of computation, it would be difficult to meaningfully translate evolutionary principles into architectural design. Together, evolution, genetics, and computation form the conceptual and technical framework that underpins the development of evolutionary architecture.

Although the concept of evolution has roots in ancient thought, it was Charles Darwin who articulated the theory in its modern scientific form (Freeman and Herron, 2014). With the publication of Darwin's work, the long-held belief that living species were fixed and unchanging gave way to an understanding of life as dynamic and continuously shaped by complex evolutionary mechanisms (Monod, 1971). Recognizing that the formation, transformation, and extinction of species are governed by evolutionary processes introduced a new perception of nature based on variability, adaptation, and contingency. Advances in evolutionary biology further revealed that living organisms change through mechanisms such as mutation, variation, and natural selection. This paradigm shift not only transformed scientific understanding but also redefined how nature was conceptualized within architectural discourse, moving it from a static ideal to a dynamic and evolving system.

Although Darwin proposed many foundational mechanisms in his theory of evolution, including natural selection and variation, he lacked a scientific understanding of heredity (Ospovat, 1981). He speculated about the inheritance of traits but was unable to explain the principles behind genetic transmission. A comprehensive understanding of evolution only began to emerge with the development of genetics. The discovery of chromosomes, DNA, and gene sequencing technologies provided crucial insights into the mechanisms underlying evolutionary change (Portin, 2002). Within this framework, processes such as mutation, natural selection, and genetic drift were modeled mathematically, offering explanations for both microevolutionary and macroevolutionary patterns (Lewontin, 1974). These advancements enabled designers and theorists to explore the potential of evolutionary intelligence by engaging directly with the deep structural logic of nature, opening new possibilities for its application in architectural design.

Advancements in genetics have made it possible to analyze how organisms adapt to changing environmental conditions at multiple levels, from the genetic code to complex systemic behaviors (Portin, 2002). Rather than relying solely on external appearance or anatomical features, researchers began to study organisms through more precise indicators such as genotype, phenotype, morphology, and developmental processes (Futuyma and Kirkpatrick, 2023). As a result, the adaptive strategies produced through evolution could be understood across micro and macro scales, offering a richer and more objective understanding of biological intelligence. These insights have informed diverse approaches in evolutionary architecture, where biological solutions are translated into design strategies. In this context, genetics serves as a crucial descriptive framework for understanding evolutionary processes and thus represents the second key theoretical foundation of evolutionary architecture.

Evolutionary mechanisms are not governed by fixed or linear equations but instead operate through non-linear and highly complex parameters (Fogel, 1998). The full complexity of these processes often exceeds the cognitive limits of the human mind. However, advancements in computer science have made it possible to abstract, translate, and model the internal logic of evolutionary mechanisms in digital form (Bentley, 1999). Through computational simulation, designers can replicate and explore evolutionary processes that unfold over millions of years, enabling rapid testing and evaluation within virtual environments (Mitchell, 1998). As a result, computational representations of nature's evolutionary dynamics have become an essential tool in the development of evolutionary architecture, facilitating experimental and generative design strategies that mirror biological processes.

Computation plays a critical role in revealing the internal dynamics of evolution by enabling the modeling of complex and interactive systems. Computational frameworks allow evolutionary processes to be observed, manipulated, and analyzed in real time within digital environments. Through algorithmic control and parametric responsiveness, computation demonstrates how small changes in input conditions can lead to significant shifts in form and behavior over time. This makes the iterative and nonlinear character of evolution both visible and operative within design processes. By translating biological principles into digital logic, computation does not merely imitate evolutionary processes but exposes their generative rationale. This opens new opportunities for form development, environmental responsiveness, and systemic organization in architectural design.

The introduction and advancement of computational systems have also enabled architects to construct virtual evolutionary environments in which architectural forms evolve according to digital representations of selection and variation mechanisms. Within these environments, numerous design alternatives can be generated, evaluated, and refined quickly, offering both conceptual flexibility and practical efficiency. Computation functions not only as a simulation tool but also as a medium for experimental exploration, reflecting the adaptive and iterative nature of evolution. It enables the application of trial-and-error logic, which is central to evolutionary processes, within the context of design. In this way, computation provides a critical medium through which the core principles of evolution can be actively investigated and tested in architectural design. Thus, computation plays a vital role in reinforcing the theoretical foundations of evolutionary architecture.

Supported by developments in genetics and computation, the evolutionary understanding of nature has promoted a process-based view of both the living and non-living world. This shift has significantly influenced architectural thinking. John Frazer concentrated on the internal mechanisms of evolution, applying processes such as variation and selection as tools for generating architectural form through computation. In contrast, Eugene Tsui viewed evolution as a pathway toward refinement, treating the outcomes of natural selection as optimal solutions that could be translated into architectural design. Together, they illustrate the conceptual split between process-oriented and object-oriented approaches, establishing a foundation for ongoing discourse on the role of evolution theory in architectural design theories and practices.

## PROCESS ORIENTED EVOLUTIONARY ARCHITECTURE: JOHN FRAZER

In the preface to John Frazer's *An Evolutionary Architecture* (1995), cybernetician Gordon Pask described the book's central thesis as understanding architecture as a living, changing, and evolving system, much like nature itself. In this view, the architect's role is no longer to design static buildings or cities but to facilitate environments that are capable of coevolving with their context (Frazer, 1995b). Frazer's approach to evolutionary architecture incorporated rational models of natural evolution into the design process. Form generation procedures were explored through morphogenetic principles and evolutionary mechanisms within digital environments. Architecture, in this context, was conceived as a form of artificial life that aimed to reproduce the dynamic, adaptive, and self-organizing characteristics of nature through the capacities of digital computation.

Drawing inspiration from natural forms and structures has been a consistent theme throughout architectural history. However, the fundamental distinction in Frazer's evolutionary architecture lies in his use of the internal logic of morphological and evolutionary processes in nature as a generative design method. Rather than imitating appearances, Frazer sought to simulate the rules that govern natural evolution through computational systems, allowing form to emerge and develop within virtual environments. These forms evolved in response to environmental factors, functioning as computational equivalents of natural selection. According to Frazer, when a system reaches a certain level of complexity, it begins to self-organize and replicate, generating increasingly complex structures (Frazer, 1995a). This approach represented a significant paradigm shift, as it reduced the designer's direct control and embraced the autonomy of the evolutionary process in producing architectural forms that could exceed the limits of human imagination.

The question of whether the evolutionary process has an underlying purpose has been debated for centuries. Richard Dawkins argued that natural selection, which operates without foresight or intelligence, is sufficient to explain the complexity of life without the need for an intelligent designer (Dawkins, 1996). In contrast, Theodosius Dobzhansky viewed evolution as a purposeful process, envisioning a kind of creation through evolution guided by a designer (Dobzhansky, 1973). In architecture, design is traditionally shaped by the intentions of the architect and oriented toward a predetermined outcome. However, evolutionary processes do not allow for such certainty. In Frazer's model, designers often remained unaware of the final form, even when the expectations for the design were clearly defined (Frazer, 1995b). The focus was not on predicting or controlling the result but on structuring the evolutionary process itself as a means of generating architectural form.

Numerous developments in computer science, including Turing machines, self-replicating automata, cellular automata, genetic algorithms, and classifier systems, provided both the conceptual foundations and technical tools necessary to simulate evolutionary processes within computational environments. Alan Turing explored the mathematical modeling of morphogenetic processes, contributing to an early understanding of biological pattern formation (Turing, 1952). John von Neumann investigated the potential for one automaton to create another, laying the groundwork for systems of self-reproduction and evolution within machines (Von Neumann, 1966). Stephen Wolfram extended these ideas through his work on cellular automata, a mathematical model for simulating complex natural systems composed of simple, locally interacting components (Wolfram, 1984). These foundational studies were significant for John Frazer's theory of evolutionary architecture because they supported his aim to design conceptual machines capable of modeling the logic and behavior of evolutionary systems.

John Holland contributed to the theoretical foundation of Frazer's evolutionary architecture by developing adaptive models based on advancements in genetic algorithms and classifier systems. Drawing on Neo-Darwinian principles, Holland formulated the adaptation process through key mechanisms such as chromosomes, mutation, recombination, and fitness evaluation. He also proposed an adaptive classifier system that receives information from the environment, evaluates it against a set of conditional rules, and generates an appropriate response (Holland, 1975). This process can be understood as an abstraction of a living organism that perceives its environment, processes information, and takes action. Genetic algorithms and classifier systems supported Frazer's model by enabling the quantitative specification of design problems, defining selection criteria, and incorporating machine learning techniques that allow the system to adapt to changing environmental conditions.

The evolutionary design process proposed by Frazer focused on simulating key natural phenomena such as natural selection, self-organization, metabolism, thermodynamics, morphogenesis, and symmetry-breaking within architectural contexts. This model required an architectural concept that could be defined in terms of a genetic code. To construct such a code, it was necessary to develop a universal architectural framework capable of adapting to diverse environments through different structural and spatial configurations. The resulting code was then translated into a series of models within a computer simulation, where form generation was driven by the interaction between encoded instructions and environmental variables. These models were evaluated, and the more successful variants were reintroduced into the system to repeat the process. This iterative cycle continued until a particular developmental stage was selected for physical prototyping **(Figure 1)**. Because the design process relied on a combination of encoded logic and environmental feedback, the resulting forms were often unpredictable and emerged through complex interactions rather than predefined rules.

One of the projects developed by Frazer was the Universal Interactor, which aimed to integrate environmental factors into the development of genetic codes and the selection of successful architectural forms. A series of experimental antennas were installed to act as transmitters and receivers, facilitating interaction between the environment and the evolving design model. The receptors responded to inputs such as motion, sound, and color, while the transmitters emitted signals in the form of light, sound, and movement (Frazer, 1995b). Environmental data collected by the antennas was converted into digital information, enabling communication with the evolving architectural model. The classifier system then combined this environmental input with internal operational rules to determine the system's adaptive response. As a result, both the environment and the architectural models evolved within the same digital medium, creating a symbiotic relationship between context and form in the simulation.

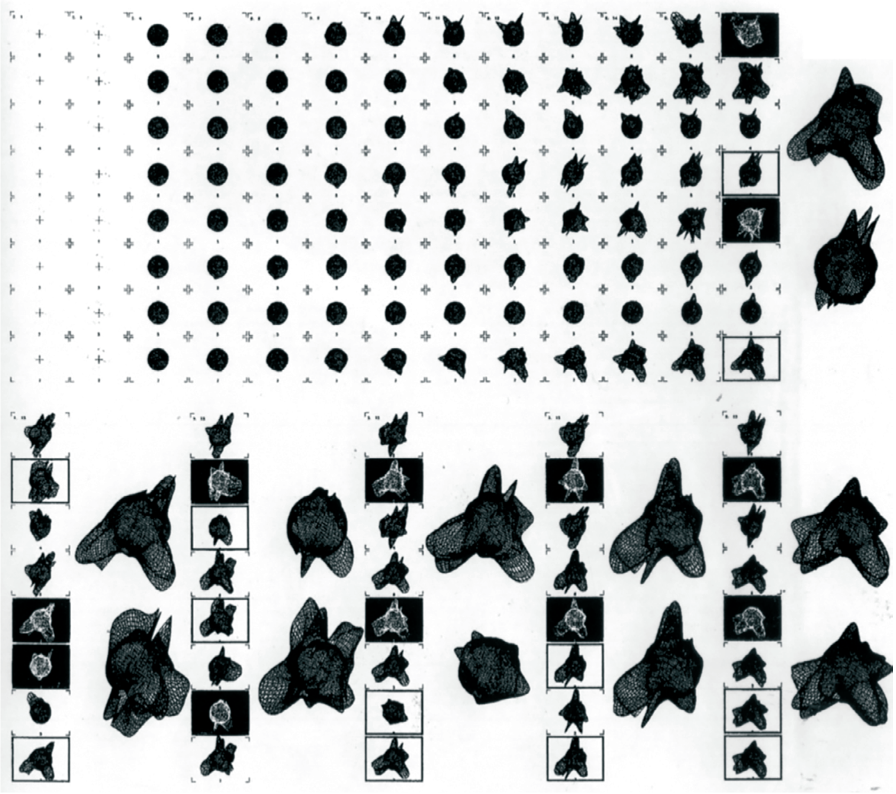

**Figure 1.** Evolving architectural form depending on environmental feedback, Ichiro Nagasaka's project (Frazer, 1995b, 79).

Frazer's model of evolutionary architecture proposes a process-oriented methodology for architectural design. At its core, there is an emphasis on the transformation of matter from simple to complex structures through developmental processes. This approach integrates the evolution of architectural concepts with both internal design dynamics and external environmental influences. Frazer simulated the operation of natural evolutionary mechanisms in the virtual environment using digital computation to guide the developmental stages of architectural form. In this framework, the architect's primary task is not to define final formal, structural, or material outcomes, but rather to translate the underlying principles of natural processes into architectural design. The focus shifts from predicting or prescribing specific results to enable the emergence of complex forms through evolutionary logic.

A major limitation of Frazer's approach is rooted in the constraints of digital computation when representing biological processes. Although genetic algorithms and simulations can model certain aspects of evolutionary behavior, they tend to oversimplify the dynamic and embodied nature of biological evolution. Natural systems evolve through complex interactions with physical, chemical, and ecological forces across long time spans, incorporating unpredictability, failure, and material feedback. Digital environments, by contrast, often operate with predefined parameters and limited variables, which restrict the authenticity of simulated evolution. As a result, the architectural forms generated may be formally compelling but can remain difficult to translate into real-world applications in terms of performance, constructability, or environmental responsiveness. This disconnect raises concerns about the feasibility of translating computational experiments into built architectural solutions that perform effectively in real environmental and material contexts.

## OBJECT ORIENTED EVOLUTIONARY ARCHITECTURE: EUGENE TSUI

In the preface to Eugene Tsui's Evolutionary Architecture: Nature as a Basis for Design (1999), Louis L. Marines emphasized the book's focus on environmental responsibility, efficient resource use, and the importance of returning to nature as a foundation for design thinking. For Tsui, the principles of evolutionary architecture were found in the structural formations and systems present in nature. Technological tools served as instruments for transferring these principles into architectural design. He argued that nature had spent millions of years creating and refining structural solutions through evolutionary processes. As a result, he believed that architects should learn from and apply the knowledge embedded in these outcomes when designing the built environment (Tsui, 1999). This approach stood in contrast to John Frazer's process-oriented model, as Tsui did not aim to simulate evolutionary mechanisms but instead focused on the final forms, structures, and material organizations produced by natural evolution.

Tsui did not focus on aesthetic visuality in nature but rather on the functional principles of organisms. He argued that interpreting the universe as a closed system governed by fixed and mechanical relationships led to static, unresponsive, and rigid built environments. Buildings designed within this framework tended to exhibit Cartesian, uniform, and flat characteristics. In contrast, Tsui understood the universe as an open system shaped by change, disorder, and evolution. These features allowed for the formation of complex and adaptive organizations. Although some scientists and philosophers described evolution as random and chaotic (Bonner, 2013; Dawkins, 1996), Tsui recognized a pattern of order and a tendency toward perfection within evolutionary development (Kamaoğlu, 2021). Based on this view, his evolutionary architecture promoted responsive building components, continuity between structure and surface, spatial variability, and non-uniform planning strategies.

Living organisms evolved through long processes of trial and error, in which successful adaptations were preserved and unsuitable traits were eliminated. The species that exist today are the result of this extensive evolutionary development. According to Tsui, evolutionary processes demonstrated that nature gradually implemented engineering improvements that directly enhanced an organism's functional efficiency and purpose (Tsui, 1999). In this context, the evolutionary model offered a valuable design method, as it had the potential to arrive at highly optimized solutions using only the materials available to the architect. Tsui conceived of buildings as living organisms, each containing specific functional processes and programs. Through this analogy, the architect could emulate nature's design intelligence within a much shorter timeframe than the geological timescale over which natural evolution occurred.

Tsui's evolutionary architecture theory placed strong emphasis on the form of the building. He recommended the use of forms that effectively dissipated tension and strain, and that expressed the structural, material, and spatial economy observed in nature. Designed spaces were expected to be dynamic and continuous rather than static and compartmentalized. Beyond formal considerations, Tsui promoted the concept of a living building that could adapt to changing environmental conditions and human needs. Buildings, in his view, should include sensitive components that respond to their surroundings. He also advocated for the use of recycled and non-toxic building materials to reduce pollution and to enhance the physical and mental well-being of occupants. Tsui aimed to implement these principles by studying organisms that had survived and adapted through extended evolutionary development.

After outlining the principles of evolutionary architecture in his book, Tsui explored the lessons that could be drawn from nature through the study of natural forms and laboratory-based design research. These natural forms included, but were not limited to, parabolic shapes, hemispheres, membranes, and cylinders. In his experimental work, Tsui subjected these forms to various tests for strength, weight, compression, tension, and aerodynamic behavior using wind tunnels. He also observed living organisms under a microscope and examined biological structures such as bones and nasal passages to understand their design logic and functional purpose (Tsui, 1999). The primary goal of these laboratory investigations was to establish objective and measurable interpretations of natural design principles. The insights gained from these experiments were then applied to architecture in the form of structural, formal, and material strategies.

One of the buildings designed by Tsui based on his evolutionary architecture theory was the Tsui House **(Figure 2)**, constructed between 1993 and 1995. The walls of the house were angled inward by four degrees to resist lateral forces generated by strong earthquakes. The elliptical form of the structure featured curvilinear continuity, which was intended to distribute loads evenly across the surface and avoid concentrated stress points. This structural strategy enhanced the internal strength of the frame while minimizing surface area (Kamaoğlu, 2021). To address wind behavior, Tsui curved the outer walls in order to disperse wind currents more effectively across the building's surface. In addition, the dimpled texture of the facade was designed to reduce wind drag and improve aerodynamic performance. These design choices demonstrated how architectural form could be optimized to meet environmental conditions


**Figure 2.** Tsui House, photo credit: John Storey (Dalzell, 2015).

through static structural configurations rather than through responsive or kinetic systems.

The Tsui House was also conceived as a living organism capable of actively responding to natural conditions specific to its location. Subsurface solar air tubes, covering much of the upper portion of the house, absorbed heat from the sun during the day. At night, this stored heat was redirected into the interior to regulate the building's temperature. The logic behind this passive heating system was inspired by the bone and capillary structures of the extinct reptiles Dimetrodon and Stegosaurus. Both species featured plate-like structures along their backs that were surrounded by blood vessels, allowing solar energy to help regulate their body temperatures. This design demonstrated that Tsui studied not only organisms that had survived through evolution but also those that had become extinct, extending his research across the full spectrum of evolutionary development.

Tsui's evolutionary architecture model emphasized the importance of applying the solutions developed by organisms through evolutionary processes to architectural design. Within this perspective, a building's interaction with the environment remained essential, as responsiveness was understood to be a fundamental characteristic of nature. However, Tsui did not incorporate the mechanisms of evolution such as mutation, variation, or natural selection into the design process. Unlike Frazer, who explored digital computation to simulate evolutionary dynamics in abstract terms, Tsui focused primarily on the computational potential of materials to achieve structural stability and environmental responsiveness. His design approach aimed to enhance performance through physical form and material behavior. In summary, Tsui treated the formal, structural, and material configurations of organisms as complete and refined outcomes that could be directly translated into architectural design solutions.

Tsui's biologically inspired design approach reveals important limitations related to the differences between biological organisms and architectural structures. While natural evolution produces highly adapted solutions, transferring those outcomes into architecture cannot be achieved through one-to-one replication. Architectural projects must respond to a range of conditions, including human use, cultural expectations, material constraints, and construction practices, which differ significantly from the selective pressures shaping biological systems. Simply adopting the form, structure, or material of an organism does not necessarily carry over the intelligence or agency embedded in living systems. These qualities emerge from dynamic interactions that are often difficult to reproduce in the built environment. Tsui's work foregrounds the value of learning from nature, but it also illustrates the challenge of interpreting biological knowledge in ways that are both meaningful and contextually appropriate for architecture.

## CONCLUSION: PROCESS VERSUS OBJECT

The relationship between nature and architecture has been interpreted through a variety of design theories and methodologies, shaped by cultural contexts, technological capabilities, and prevailing conceptions of nature. Following the emergence of evolutionary theory and its profound influence on how the physical world is understood, some architects began to investigate the potential of evolutionary processes as frameworks for

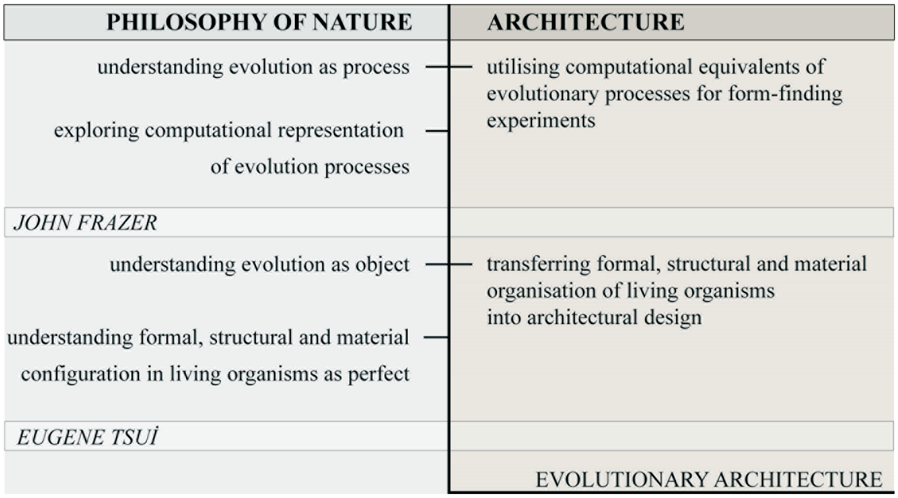


**Figure 3.** Process versus object in evolutionary architecture theories of John Frazer and Eugene Tsui (Kamaoğlu, 2020).

architectural design. Among these, John Frazer and Eugene Tsui presented two distinct approaches in the 1990s that exemplified divergent responses to evolution in architecture. Their work helped shape later discourse by framing evolution either as a generative process or as a source of refined outcomes. The process-oriented approach focused on simulating evolutionary mechanisms such as variation and selection to generate architectural form. In contrast, the object-oriented approach drew on the forms, materials, and structures of biological organisms as design solutions informed by the results of natural evolution **(Figure 3)**.

Frazer's process-oriented approach to evolutionary architecture relied heavily on simulating evolutionary models within computational environments to generate and test emerging architectural forms. In this framework, evolution functioned as a procedural logic for design, implemented through the use of genetic algorithms. All stages of form development took place in the digital realm. However, the computational model offered only an abstract and simplified representation of evolutionary dynamics as they occur in the natural world. As a result, the connection between Frazer's design methodology and the physical environment remained relatively limited. Despite this constraint, the strength of his approach lays in its capacity to generate a wide range of formal outcomes and to assess them against specific performance or aesthetic criteria. This design process enabled new modes of architectural experimentation by allowing for the rapid and iterative exploration of formal possibilities within a virtual setting.

Tsui's object-oriented understanding of evolutionary architecture focused primarily on the final forms of organisms, which embodied a range of solutions developed in response to specific environmental conditions, structural demands, and material constraints. While these outcomes were the result of long evolutionary processes involving millions of years of trial-and-error, Tsui did not emphasize the process itself. Instead, he saw the intelligence of evolution as residing in the refined forms that emerged from it. The central challenge of this approach was translating biological solutions into architectural contexts. Since it is not possible to replicate nature directly, any attempt at mimicry required technological interpretation and adaptation. Despite this limitation, Tsui's approach offered a compelling design methodology that positioned architecture as a living system. His work avoided conventional stylistic categories and instead drew on what he regarded as the accumulated wisdom of natural evolution.

Revisiting the approaches of John Frazer and Eugene Tsui offers valuable insight into the ongoing challenges and possibilities of applying evolutionary frameworks in contemporary architectural design. Their work highlighted two foundational strategies: the simulation of evolutionary processes through computation and the translation of biological outcomes into built form. Frazer's focus on digital simulation emphasized issues of process, autonomy, and formal variation, while Tsui's focus on biological intelligence brought attention to adaptation, structural efficiency, and material performance. Together, their methodologies revealed the creative potential and practical limitations of using evolutionary models in design. As architecture continues to respond to ecological, technological, and material complexities, their contrasting visions remind us that the use of evolution in design requires not only technical capacity but also thoughtful interpretation of how natural systems are understood and applied within the built environment.

Humans do not have direct access to the fundamental fabric of reality. Instead, we construct concepts, paradigms, theories, and models to understand and interpret nature. Understanding evolution as a process or as an object should not be seen as conflicting, but as two complementary ways of engaging with the natural world. Nothing in nature can be considered final or unchanging, since all things exist in a continuous state of transformation. For architects, the challenge is to consider how each understanding of evolution can contribute to creating more adaptive, inclusive, and ecologically responsible built environments for both human and non-human species. Ultimately, recognizing evolution as process and as object reflects two sides of the same inquiry. The evolutionary architecture theories of John Frazer and Eugene Tsui offered important demonstrations of these perspectives in the early 1990s, and they continue to shed light on contemporary architectural discourse.

## REFERENCES

ALLSOPP, B. (1959) *A History of Renaissance Architecture*, Pitman, London

ANDERSON, C. (2013) *Renaissance Architecture*, Oxford University Press, Oxford.

BENTLEY, P. J., ed. (1999) *Evolutionary Design by Computers*, Morgan Kauffman Publishers, San Francisco.

BONNER, J. T. (2013) *Randomness in Evolution*, Princeton University Press, Princeton.

CEVIZCI, A. (2018) *Felsefe Tarihi: Thales'ten Baudrillard'a*, Say Yayınları, İstanbul.

CHING, F. D., JARZOMBEK, M. M., PRAKASH, V. (2017) *A Global History of Architecture*, John Wiley & Sons, New Jersey.

COGDELL, C. (2018) *Toward a Living Architecture? Complexism and Biology in Generative Design*, University of Minnesota Press, Minneapolis.

COLLINGWOOD, R. G. (1945) *The Idea of Nature*, Clarendon Press, Oxford.

COYNE, R. (2018) *Network Nature: The Place of Nature in the Digital Age*, Bloomsbury Academic, London and New York.

CRUZ, M., BECKETT, R. (2016) Bioreceptive Design: A Novel Approach to Biodigital Materiality, *Architectural Research Quarterly* 20(1) 51-64.

DADE-ROBERTSON, M. (2020) *Living Construction*, Routledge, New York.

DALZELL, T. (2015) How Quirky is Berkeley? Eugene Tssui's Fish House, Part 1, *Berkeleyside* https://www.berkeleyside.org/2015/11/30/how-quirky-is-berkeley-eugene-tssuis-fish-house-part-1 Date accessed (07.05.2024)

DARWIN, C. (1859) *On the Origin of Species by Means of Natural Selection, or The Preservation of Favoured Races in the Struggle for Life*, John Murray, London.

DAWKINS, R. (1996) *The Blind Watchmaker: Why the Evidence of Evolution Reveals a Universe Without Design*, Norton, New York.

DEMING, D. (2014) *Science and Technology in World History Volume 3: The Black Death, the Renaissance, the Reformation and the Scientific Revolution*, McFarland & Company, North Carolina.

DOBZHANSKY, T. (1973) Nothing in Biology Makes Sense Except in the Light of Evolution, *The American Biology Teacher 35*(3) 125-29.

DOXIADIS, C. A. (1972) *Architectural Space in Ancient Greece*, ed. and trans. J. Tyrwhitt, MIT Press, Massachusetts.

FOGEL, D. B., ed. (1998) *Evolutionary Computation: The Fossil Record*, IEEE Press, New Jersey.

FRAZER, J. (1995A) Architectural Experiments, *Architectural Design 65*(11-12) 78-79.

FRAZER, J. (1995B) *An Evolutionary Architecture*, Architectural Association, London.

FREEMAN, S., HERRON, J. C. (2014) *Evolutionary Analysis*, Pearson, Boston.

FUTUYMA, D. J., KIRKPATRICK, M. (2023) *Evolution*, Oxford University Press, Oxford.

GAUKROGER, S. (2002) *Descartes' System of Natural Philosophy*, Cambridge University Press, Cambridge.

GAYON, J. (2016) From Mendel to Epigenetics: History of Genetics, *Comptes Rendus Biologies* 339(7-8) 225-30.

HENSEL, M., MENGES, A., WEINSTOCK, M., eds. (2004) *Emergence: Morphogenetic Design Strategies*, Wiley-Academy, London.

HOLLAND, B. (2010) Computational Organicism: Examining Evolutionary Design Strategies in Architecture, *Nexus Network Journal* 12(3) 485-95.

HOLLAND, J. H. (1975) *Adaptation in Natural and Artificial Systems: An Introductory Analysis with Applications to Biology, Control, and Artificial Intelligence*, The University of Michigan Press, Michigan.

HUXLEY, J. S. (2010) *Evolution: The Modern Synthesis,* The MIT Press, Massachusetts.

IRELAND, T. (2024) *From Life to Architecture, to Life*, Springer, Cham.

JORDAN, R. F. (1984) *A Concise History of Western Architecture*, Harcourt Brace Jovanovich, New York.

KAMAOĞLU, M. (2020) *Evrimsel Mimarlığın Doğa Felsefesi-Mimarlık İlişkisi Üzerinden Değerlendirilmesi*, unpublished Master's Thesis, Karadeniz Technical University, Trabzon.

KAMAOĞLU, M. (2021) Mimarlıkta İlerlemeci Bir Süreç Olarak Evrim ve Eugene Tsui'nin Evrimsel Mimarlık Yaklaşımı, *Evrim Ağacı* https://evrimagaci.org/evrimsel-mimarliga-giris-mimarlikta-ilerlemeci-bir-surec-olarak-evrim-ve-eugene-tsuinin-evrimsel-mimarlik-yaklasimi-10562 Date accessed (06.05.2024)

KAMAOĞLU, M. (2023A) *Digital Neo-Darwinism in Architecture: From Logic to Materiality*, 5th International Conference for BioDigital Architecture & Genetics, ed. Alberto T. Estévez, KIT-BOOK Servicios Editoriales, Barcelona; 332-42.

KAMAOĞLU, M. (2023B) The Idea of Evolution in Digital Architecture: Toward United Ontologies?, *International Journal of Architectural Computing* 21(4) 622-34.

LEWONTIN, R. C. (1974) *The Genetic Basis of Evolutionary Change*, Columbia University Press, New York and London.

LYNN, G. (2000) Embryologic Houses, *Architectural Design* 70(3) 26-35.

MITCHELL, M. (1998) *An Introduction to Genetic Algorithms*, The MIT Press, Massachusetts.

MOLLAND, G. (1993) Science and Mathematics from the Renaissance to Descartes, *Routledge History of Philosophy Volume 4: Renaissance and Seventeenth-Century Rationalism*, ed. G. H. R. Parkinson, Routledge, London; 104-39.

MONOD, J. (1971) *Chance and Necessity: An Essay on the Natural Philosophy of Modern Biology*, Alfred A. Knopf, New York.

OSPOVAT, D. (1981) *The Development of Darwin's Theory: Natural History, Natural Theology, and Natural Selection, 1838-1859*. Cambridge University Press, Cambridge.

PORTIN, P. (2002) Historical Development of the Concept of the Gene, *The Journal of Medicine and Philosophy* 27(3) 257-86.

ROTH, L. M. (2018) *Understanding Architecture: Its Elements, History, and Meaning*, Routledge, New York and London.

RUSSELL, B. (2004) *History of Western Philosophy*, Routledge, London.

RUTH, M., BEN, B., LOUISE, M., eds. (2023) *Bioprotopia: Designing the Built Environment with Living Organisms*, Birkhäuser, Basel.

STEADMAN, P. (2008) *The Evolution of Designs: Biological Analogy in Architecture and the Applied Arts*, Routledge, London.

TSUI, E. (1999) *Evolutionary Architecture: Nature as a Basis for Design*, John Wiley & Sons, New York.

TURING, A. M. (1952) The Chemical Basis of Morphogenesis, *Philosophical Transactions of the Royal Society of London, Series B, Biological Sciences* 237(641) 37-72.

VITRUVIUS, P. (1914) *Vitruvius: The Ten Books on Architecture*, trans. M. H. Morgan, Harvard University Press, Massachusetts.

VON NEUMANN, J. (1966) *Theory of Self-Producing Automata*, ed. A. W. Burks, University of Illinois Press, Urbana and London.

WATKIN, D. (2005) *A History of Western Architecture*, Laurence King, London.

WITTKOWER, R. (1988) *Architectural Principles in the Age of Humanism*, Academy Editions, London.

WOLFRAM, S. (1984) Cellular Automata as Models of Complexity, *Nature* 311(5985) 419-24.

**Alındı:** 16.05.2024; **Son Metin:** 26.08.2025

**Anahtar Sözcükler:** Evrimsel mimarlık; doğa felsefesi; evrim kuramı; hesaplamalı tasarım; mimarlık kuramı.

## SÜREÇ NESNEYE KARŞI: JOHN FRAZER VE EUGENE TSUI'NİN EVRİMSEL MİMARLIK KURAMLARI

Evrim teorisinin ortaya çıkışından önce, doğa felsefesi ile mimarlık arasındaki ilişki durağan bir dünya görüşüne dayanıyordu. Evrim teorisinin gelişimi, doğayı değişim, çeşitlenme ve sürekli dönüşüm üzerinden tanımlayan dinamik bir anlayışla bu bakış açısını kökten dönüştürdü. Bu makale, evrim teorisinin mimari tasarım düşüncesini nasıl etkilediğini, 1990'lı yılların başında John Frazer ve Eugene Tsui tarafından geliştirilen iki farklı ve öncü yaklaşımı inceleyerek ele almaktadır. Çalışma, evrimsel mimarlıkta iki temel yönelimi tanımlamaktadır. İlki, evrimi bir süreç olarak ele alır; mutasyon, varyasyon ve seçilim gibi mekanizmaları temel alarak bu süreçleri hesaplamalı simülasyonlar aracılığıyla mimari form üretiminde kullanır. İkincisi ise evrimi bir sonuç olarak görür; doğal seçilim yoluyla ortaya çıkan biyolojik organizmaların biçimsel, yapısal ve maddi zekasından yararlanarak tasarım stratejileri geliştirir. Frazer ve Tsui bu yaklaşımların temsilcileridir. Frazer, evrimsel dinamikleri simüle ederek parçadan bütüne mimari form üretimini modellendirmiş; Tsui ise doğal evrim sonucu ortaya çıkan biyolojik biçimleri analiz ederek mimari tasarıma aktarmaya çalışmıştır.

Her iki yaklaşım da biyoloji, genetik ve hesaplamalı kuramlardan beslenmektedir; ancak uygulamada farklı tasarım metodolojileri önermektedir. Frazer'ın modeli, hesaplama yoluyla çeşitlenen mimari formlar üretme potansiyelini gösterse de dijital ortamların biyolojik evrimin fiziksel, maddi ve ekolojik karmaşıklığını yeterince yansıtamaması nedeniyle sınırlıdır. Tsui'nin yaklaşımı ise biyolojiden ilham alarak adaptasyon, yapısal performans ve çevresel duyarlılığı ön plana çıkarır, ancak biyolojik özelliklerin mimarlığa doğrudan aktarımında zorluklarla karşılaşır. Binalar, biyolojik organizmaların aksine, kullanıcı ihtiyaçları, inşa yöntemleri, yönetmelikler ve kültürel bağlam gibi birçok etmene yanıt vermek zorundadır. Her iki model de evrim kuramının tasarıma uygulanmasındaki hem yaratıcı olanakları hem de pratik sınırlamaları ortaya koymaktadır. Mimarlık, ekolojik, teknolojik ve malzeme karmaşıklıklarıyla yüzleşmeye devam ederken, Frazer ve Tsui'nin karşıt gibi görünen yaklaşımları, evrimin tasarımda yalnızca teknik yenilikle değil, aynı zamanda doğal sistemlerin dikkatle yorumlanması ile anlam kazanabileceğini ortaya koymaktadır.

## PROCESS VERSUS OBJECT: EVOLUTIONARY ARCHITECTURE THEORIES OF JOHN FRAZER AND EUGENE TSUI

Before the introduction of evolutionary theory, the relationship between the philosophy of nature and architecture was grounded in a static worldview. Evolutionary theory disrupted this perspective by introducing a dynamic understanding of nature, defined by variation, adaptation, and continuous transformation. This article examines how evolutionary theory has influenced architectural design thinking by analyzing two divergent yet foundational approaches developed in the early 1990s by John Frazer and Eugene Tsui. The study identifies two key trajectories in evolutionary architecture. One treats evolution as a process, focusing on mechanisms such as mutation, variation, and selection, and translating these into computational simulations to generate architectural form. The other views evolution as an outcome, drawing on the refined forms, structures, and material intelligence of biological organisms to inform design strategies. Frazer and Tsui exemplify these orientations, with Frazer modeling architectural form through bottom-up digital systems that simulate evolutionary dynamics, and Tsui deriving architectural principles from top-down analysis of biological results shaped by natural selection.

Although both approaches draw from biology, genetics, and computational theory, they produce distinct methodologies. Frazer's model demonstrates the potential of computation to generate diverse architectural forms through iterative processes, but it is constrained by the limits of digital environments, which cannot fully replicate the physical, material, and ecological complexity of natural evolution. Tsui's method emphasizes adaptation, structural performance, and environmental responsiveness, yet faces challenges in transferring biological intelligence into architecture. Unlike organisms, buildings must address user needs, construction practices, codes, and cultural expectations. Both models reveal the creative possibilities and practical limitations of applying evolutionary thinking to design. As architecture continues to engage with ecological, technological, and material complexities, the contrasting visions of Frazer and Tsui underscore that evolution in design requires not only technical innovation but also careful interpretation of natural systems within built environments.

**MELİH KAMAOĞLU**; B.Arch., M.Arch., Ph.D.
Received his B.Arch. (2017) and M.Arch. (2020) from Karadeniz Technical University, and Ph.D. (2025) from the Bartlett School of Architecture, University College London. His primary research interests include bio-digital design, computation, evolution theory and philosophy of nature. melihkamaoglu@hotmail.com, melih.kamaoglu.20@alumni.ucl.ac.uk, melihkamaoglu@ktu.edu.tr

**DEMET YILMAZ YILDIRIM**; B. Arch., M.Arch., Ph.D.
Received her B.Arch. (2003), M.Arch. (2006) and Ph.D. (2011) from the Department of Architecture, Karadeniz Technical University. Her primary research interests are architectural design and urban design. yilmazdemett@hotmail.com, yilmazdemett@ktu.edu.tr