



Biophilic Architecture: Integrating Nature into Architecture for Sustainable Living and Enhanced Well-Being

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ABSTRACT

Biophilic architecture presents a transformational strategy for sustainable living and improved human well-being. This paper investigates how biophilic design principles create a symbiotic relationship between nature and architecture, enhancing the built environment in response to many of the greatest global issues facing mankind: climate change, urbanization and mental health. By thoroughly reviewing existing literature and innovative practices, the paper explores the ecological, psychological, and aesthetic advantages of biophilic architecture. The main conclusions underline how integrating nature in designed environments can lead to increased environmental sustainability, better physical and mental well-being, and more visually pleasing spaces. Finally, this paper proposes pragmatic solutions to implement the biophilic design in present-day architecture.

Keywords: biophilic design, sustainable architecture, human well-being, nature-integrated design, urban resilience, ecological architecture

1. Introduction

Biophilic architecture represents a transformative design philosophy that seeks to bridge the growing disconnection between humans and the natural world by integrating elements of nature, natural patterns, and organic processes into the built environment. This concept is deeply rooted in the theory of *biophilia*, a term popularized by Edward O. Wilson in 1984, which refers to humanity's inherent tendency to affiliate with nature and natural systems (Wilson, 1984). By incorporating features such as greenery, natural light, ventilation, water elements, and biomorphic forms, biophilic design strives to create spaces that resonate with the psychological, physiological, and ecological needs of their occupants. The relevance of biophilic architecture has become more pronounced in the context of rapid urbanization and escalating environmental challenges. Urban expansion often results in the loss of green spaces, increased pollution, and a sense of alienation from natural surroundings. These conditions contribute to a spectrum of issues, including deteriorating mental health, reduced productivity, and environmental degradation (Kellert, 2008). Biophilic architecture addresses these challenges by fostering a symbiotic relationship between urban dwellers and nature, enhancing not only individual well-being but also the sustainability of urban ecosystems.

Empirical studies underline the potential of biophilic design to mitigate the adverse effects of urban living. For instance, research has shown that access to green spaces and exposure to natural light can significantly reduce stress, improve cognitive functioning, and increase workplace productivity (Browning et al., 2014). Additionally, the incorporation of vegetation and water features has been linked to improved air quality and urban biodiversity, further demonstrating the multifaceted benefits of this architectural approach (Beatley, 2016). In practice, biophilic architecture transcends aesthetic considerations to function as a vital component of sustainable urban development. By integrating renewable materials, optimizing energy efficiency, and promoting biodiversity, this design philosophy contributes to achieving global sustainability goals. As such, it has gained traction in various architectural projects worldwide, from urban parks and green buildings to entire biophilic cities (Newman, 2019). The evolving principles of biophilic architecture underscore its potential to reshape the built environment in ways that nurture human health and ecological balance.

2.0 Literature Review

Biophilic architecture has undergone a transformative evolution, shaped by humanity's deep connection to nature and its shifting priorities in response to urbanization, industrialization, and environmental crises. This design philosophy, rooted in the innate human affinity for natural systems and environments, has progressed through distinct phases, from intuitive practices in ancient times to its formalization as a modern architectural movement.

The foundations of biophilic architecture can be traced to ancient civilizations, where designs intuitively incorporated nature as a central element.

- **Vernacular Architecture:** Traditional buildings across the world — such as Japanese tea houses, Indian courtyards, and Mediterranean atriums — utilized natural materials, passive ventilation, and open spaces to create harmony with the environment (Kellert, 2011). These designs emphasized climatic responsiveness and a spiritual connection to nature.
- **Sacred Spaces:** Structures like the Hanging Gardens of Babylon and Gothic cathedrals illustrate early examples of integrating greenery, natural light, and vertical elements inspired by nature. These designs symbolized reverence for the natural world and its divine qualities (Beatley, 2016).

The Industrial Revolution marked a shift away from nature-focused designs as urbanization and technological advancements prioritized efficiency and mass production over ecological harmony.

- **Urbanization's Impact:** Cities expanded rapidly, leading to dense, mechanized environments that disconnected individuals from natural surroundings. Joye and van den Berg (2011) highlight this era as a turning point when the human-nature bond began to erode, creating the need for biophilic restoration.
- **Reintroduction of Green Spaces:** Early urban planning responses, such as New York's Central Park designed by Frederick Law Olmsted, sought to reintroduce nature into urban landscapes, providing relief from industrial monotony.

The 20th century saw the emergence of modernist architecture, which emphasized minimalism, functionality, and technological innovation, often at the expense of natural integration. However, early environmentalist movements began to challenge this trend.

- **Frank Lloyd Wright's Organic Architecture:** Wright's designs, such as Fallingwater (1939), represented a precursor to biophilic architecture by harmonizing built structures with their natural surroundings (McHarg, 1969).
- **Rachel Carson's Influence:** Carson's *Silent Spring* (1962) and the rise of environmental consciousness in the 1960s emphasized the importance of reconnecting with nature to address ecological degradation.

The term "biophilia" was popularized by E.O. Wilson in 1984, describing humanity's inherent love for nature. This hypothesis laid the theoretical foundation for biophilic design as a formal concept.

- **Integration into Architecture:** Stephen Kellert and others expanded biophilia into the architectural realm, developing principles and frameworks for incorporating natural elements into the built environment (Kellert et al., 2011).
- **Green Building Movements:** The late 20th century also witnessed the rise of sustainable architecture, including the adoption of green roofs, living walls, and daylighting techniques, as seen in projects like Renzo Piano's California Academy of Sciences (2008).

Today, biophilic architecture is recognized as a critical design strategy for addressing urban challenges, enhancing well-being, and promoting environmental resilience.

- **High-Profile Projects:** Iconic structures such as Singapore's Marina One (2018) and Milan's Bosco Verticale (2014) showcase cutting-edge applications of biophilic principles. These projects integrate greenery, biodiversity, and innovative systems to create ecologically balanced urban spaces (Newman, 2019).
- **Global Initiatives:** The incorporation of biophilic design into green certification systems, such as LEED and WELL Building Standards, underscores its mainstream acceptance (Browning et al., 2014).

As cities grapple with climate change, resource scarcity, and population growth, biophilic architecture continues to evolve.

- **Technological Integration:** Advances in technology, such as AI and IoT, enable more sophisticated monitoring and management of biophilic systems, ensuring their functionality and sustainability (Beatley, 2016).
- **Biophilic Urbanism:** The movement has expanded beyond individual buildings to influence urban planning, as seen in initiatives like Singapore's "City in a Garden" strategy, which integrates nature throughout the urban fabric (Joye, 2007).

Below is a synthesis of the evolution of biophilic architecture presented in a tabular format:

Table 1. shows the evolution of biophilic architecture

Period	Key Features	Examples	Impact
Ancient Civilizations	<p>Vernacular Architecture: Natural materials, passive ventilation, open spaces for environmental harmony.</p> <p>Sacred Spaces: Integration of greenery, natural light, and symbolic reverence for nature.</p>	<p>Japanese tea houses, Indian courtyards, Mediterranean atriums</p> <p>Hanging Gardens of Babylon, Gothic cathedrals</p>	Highlighted a spiritual connection to nature and climatic responsiveness in designs.

Period	Key Features	Examples	Impact
Industrial Revolution	Urbanization's Impact: Dense, mechanized environments disconnected from nature. Reintroduction of Green Spaces: Urban planning efforts introduced parks for ecological balance.	New York's Central Park by Frederick Law Olmsted	Marked the erosion of the human-nature bond and early attempts to restore it through urban green spaces.
Modernist Architecture (20th Century)	Early Environmentalism: Organic architecture harmonized built structures with surroundings. Environmental Awareness: Rise of consciousness about ecological degradation.	Frank Lloyd Wright's Fallingwater (1939), Rachel Carson's <i>Silent Spring</i> (1962)	Challenged minimalism and functionality by emphasizing harmony with nature and ecological balance.
Biophilia Hypothesis (1984)	Theoretical Foundation: E.O. Wilson's hypothesis defined humanity's inherent love for nature. Framework Development: Formalization of biophilic design principles and strategies.	E.O. Wilson, Stephen Kellert, Renzo Piano's California Academy of Sciences (2008)	Popularized biophilia and integrated it into architecture as a design approach for human well-being and sustainability.
21st Century Innovations	High-Profile Projects: Advanced designs blending greenery, biodiversity, and systems. Global Initiatives: Biophilic design integrated into green building certifications.	Bosco Verticale (Milan, 2014), Marina One (Singapore, 2018), LEED, WELL Building Standards	Mainstreamed biophilic design in architecture and urban planning for ecological and social resilience.
Contemporary and Future Trends	Technological Integration: AI and IoT for monitoring and managing biophilic systems. Biophilic Urbanism: Extending biophilic principles to entire cities.	Singapore's "City in a Garden" strategy	Addresses urban challenges like climate change and promotes sustainable, resilient, and connected urban ecosystems.

3. REVIEW METHODOGY

This study employs a systematic literature review approach to explore the principles, applications, and impacts of biophilic architecture. The methodology is designed to ensure a comprehensive analysis of existing academic and practical resources, focusing on its contributions to sustainability, well-being, and architectural innovation. The review is guided by the following key research questions:

- How does biophilic architecture contribute to sustainability and environmental resilience?
- What are the psychological and physiological benefits of biophilic design?
- In what ways does biophilic architecture enhance aesthetic and innovative design practices?
- What challenges hinder the widespread adoption of biophilic principles?

A systematic search was conducted using academic databases and online repositories, including Databases Scopus, Web of Science, Science Direct, Google Scholar, and JSTOR and the Keywords "biophilic architecture," "sustainability in architecture," "human well-being and architecture," "nature in design," "biophilic urbanism," and "green building innovations". The search was limited to peer-reviewed journal articles, books, conference proceedings, and relevant industry reports published from 2000 to 2024 to ensure the inclusion of contemporary perspectives. To maintain relevance and quality, the following criteria were applied:

Criteria	Details
Inclusion Criteria	Studies focusing on biophilic design principles, sustainability, well-being, and architectural innovation.
	Case studies and examples of biophilic architecture across various building typologies.
	Research on the psychological, environmental, and economic impacts of biophilic design.
Exclusion Criteria	Articles not available in English.
	Studies with limited focus on architecture or nature integration.
	Irrelevant topics such as generic sustainability discussions without architectural context.

Data were categorized into themes such as sustainability, well-being, innovation, and barriers to adoption. These themes formed the basis for a structured narrative synthesis. To ensure the credibility of findings, cross-referencing was conducted with literature and industry guidelines. Studies with contradictory results were critically analyzed to identify gaps and future research directions. This review is limited by its focus on literature available in English and its reliance on secondary data. Additionally, while the study covers a wide range of building typologies and geographic contexts, specific regional or cultural nuances may require further exploration. By adopting this rigorous and systematic methodology, the paper provides a comprehensive and evidence-based review of biophilic architecture, highlighting its transformative potential for sustainable and human-centric design.

4. ANALYSIS

Research Question 1: How Does Biophilic Architecture Contribute to Sustainability and Environmental Resilience?

Biophilic architecture, by integrating nature into the built environment, offers significant contributions to sustainability and environmental resilience. This approach aligns with global objectives to mitigate climate change, conserve natural resources, and enhance the ecological balance of urban areas. Biophilic design reduces energy consumption through passive design strategies that incorporate natural ventilation, daylighting, and insulation provided by green roofs and walls. According to Kellert (2008), biophilic architecture leverages these elements to lower reliance on artificial heating, cooling, and lighting systems, contributing to a reduction in carbon emissions. Additionally, green infrastructure such as bioswales and rain gardens facilitates water management, conserving resources and mitigating urban flooding (Beatley, 2016). By integrating green spaces and vegetative features, biophilic architecture promotes urban biodiversity. Newman (2019) highlights that rooftop gardens, vertical forests, and landscaped courtyards create habitats for flora and fauna, fostering ecological networks even within densely populated areas. These green interventions also act as carbon sinks, improving air quality and reducing urban heat island effects. Biophilic design encourages the use of locally sourced, renewable, and biodegradable materials, minimizing the environmental footprint of construction. Browning, Ryan, and Clancy (2014) emphasize that the integration of natural materials not only reduces embodied energy but also promotes a circular economy by enabling reuse and recycling.

Green roofs and walls act as thermal regulators, protecting buildings from extreme weather conditions and extending their lifespan (Jiang et al., 2020). Furthermore, biophilic urban spaces such as parks and green corridors absorb excess rainwater, mitigate flooding, and provide thermal comfort during heatwaves, demonstrating their utility in adapting to climate challenges. Biophilic spaces foster a connection between individuals and nature, encouraging sustainable behaviours. Beatley (2016) argues that exposure to natural elements in urban environments increases environmental stewardship among communities. This awareness can lead to collective action for conservation and sustainable living practices. The integration of biophilic principles into architecture is instrumental in addressing sustainability and environmental resilience. Through energy efficiency, biodiversity conservation, climate adaptation, and community engagement, biophilic design transforms urban spaces into eco-friendly and adaptable environments. Future research and practice should continue to refine these strategies, ensuring their widespread application across diverse geographic and cultural contexts.

Research Question 2: What Are the Psychological and Physiological Benefits of Biophilic Design?

Biophilic design enhances the human experience by addressing the intrinsic need to connect with nature. This connection positively impacts psychological well-being and physiological health, making it an essential component of contemporary architecture aimed at improving quality of life. The presence of natural elements in the built environment has been linked to significant reductions in stress levels. Kaplan's (1995) Attention Restoration Theory suggests that exposure to nature facilitates recovery from mental fatigue, improving focus and reducing stress. Similarly, Ulrich et al. (1991) found that views of greenery accelerate recovery from surgery, demonstrating the restorative power of biophilic elements. Natural light, greenery, and organic shapes incorporated into biophilic designs improve cognitive performance and workplace productivity. Browning, Ryan, and Clancy (2014) report that biophilic office environments boost creativity and problem-solving skills, with employees experiencing a 15% increase in productivity compared to conventional office settings. This is attributed to improved mood, reduced distractions, and a greater sense of comfort.

Biophilic design fosters positive emotional states through sensory engagement with natural features. Joye and van den Berg (2011) suggest that exposure to nature-inspired designs stimulates feelings of tranquility and happiness, mitigating symptoms of anxiety and depression. These effects are particularly pronounced in urban settings, where access to natural landscapes is often limited. The physiological benefits of biophilic design are well-documented. Regular exposure to natural light regulates circadian rhythms, improving sleep quality and overall health (Figueiro et al., 2017). Additionally,

incorporating plants into indoor spaces enhances air quality by reducing carbon dioxide levels and filtering toxins, thereby reducing the incidence of respiratory illnesses (Wolverton et al., 1989). Biophilic spaces encourage social interactions, fostering a sense of community. Beatley (2016) argues that green urban areas and shared biophilic spaces promote social cohesion by providing common grounds for recreation and engagement, enhancing collective well-being. Biophilic design offers substantial psychological and physiological benefits, ranging from stress reduction and cognitive enhancement to improved social interactions and physical health. These benefits underscore the importance of integrating biophilic principles into architectural practices to create environments that nurture human well-being.

Research Question 3: In What Ways Does Biophilic Architecture Enhance Aesthetic and Innovative Design Practices?

Biophilic architecture not only addresses environmental and human well-being concerns but also transforms aesthetic and design paradigms. By integrating natural elements and processes into built environments, biophilic design fosters creativity, visual appeal, and architectural innovation. Biophilic architecture enhances aesthetics by mimicking natural forms, patterns, and textures, creating visually pleasing environments. Kellert et al. (2011) identify biomimicry as a key strategy in biophilic design, where shapes and patterns found in nature inspire organic and harmonious designs. Examples include fractal geometries, flowing lines, and adaptive structures, which resonate with human visual preferences. Biophilic architecture redefines spatial boundaries by integrating indoor and outdoor spaces. Features such as green walls, skylights, and open courtyards create seamless transitions, fostering an immersive experience of nature. Joye (2007) notes that this approach enhances spatial aesthetics and creates a sense of openness and continuity, redefining traditional architectural norms. Biophilic design promotes the use of sustainable and innovative materials, enhancing both aesthetics and environmental performance. Browning, Ryan, and Clancy (2014) emphasize that the integration of locally sourced, renewable, and tactile materials — such as timber, bamboo, and stone — contributes to an authentic and timeless aesthetic. These materials are often left in their raw or minimally processed states, highlighting their natural beauty.

Biophilic design creates dynamic spaces that engage multiple senses, elevating the user experience. Incorporating features such as flowing water, natural light, and aromatic vegetation provides a sensory-rich environment, which enhances the aesthetic appeal of the space. Pallasmaa (2012) argues that this multi-sensory engagement fosters emotional and intellectual connections, making spaces more meaningful and memorable. Biophilic design challenges architects to innovate by integrating complex ecological systems into their projects. For instance, vertical forests, such as Bosco Verticale in Milan, exemplify how biophilic principles inspire groundbreaking architectural solutions that combine ecological, structural, and aesthetic goals (Newman, 2019). These designs require the application of advanced engineering techniques and creative problem-solving, pushing the boundaries of conventional architecture. Biophilic architecture draws on cultural narratives and regional identities, creating spaces that are contextually relevant and aesthetically significant. For example, Japanese Zen gardens and traditional Indian courtyards reflect a profound connection with nature while enhancing the cultural and visual appeal of the design (Beatley, 2016). Such culturally inspired biophilic designs resonate deeply with users, enhancing their sense of belonging. Biophilic architecture redefines aesthetic and innovative design practices by incorporating natural forms, creating sensory-rich experiences, and challenging traditional spatial norms. By blending ecological consciousness with artistic creativity, biophilic design has become a catalyst for transformative architecture that inspires, engages, and evolves.

Research Question 4: What Challenges Hinder the Widespread Adoption of Biophilic Principles?

Despite its proven benefits for human well-being, environmental sustainability, and architectural innovation, the adoption of biophilic principles in mainstream architecture faces several significant challenges. These challenges are rooted in economic, social, technical, and policy-related factors that hinder the seamless integration of biophilic design into modern architectural practices. One of the primary barriers to adopting biophilic design is the perception of high upfront costs. Installing green walls, natural lighting systems, and water features often requires specialized materials and technologies, which can be cost-prohibitive. Newman (2019) points out that these investments, although cost-effective in the long term, deter stakeholders focused on short-term financial returns. Additionally, maintenance costs for living systems, such as vertical gardens and indoor plants, further contribute to this economic barrier. A limited understanding of biophilic principles among architects, developers, and policymakers is another obstacle. Kellert et al. (2011) argue that while awareness of sustainable practices has grown, biophilic design remains underrepresented in architectural education and professional training. This knowledge gap prevents designers from fully embracing biophilic strategies or effectively communicating their benefits to clients.

Urban planning regulations and zoning laws often do not accommodate biophilic elements. For instance, building codes may restrict innovative features like green façades or rooftop gardens, citing structural or safety concerns. Beatley (2016) highlights that the absence of supportive policies and incentives limits the incorporation of biophilic design in urban projects. In densely populated cities, space constraints make it challenging to incorporate biophilic elements. Vertical gardens, green roofs, and open courtyards compete with the demand for commercial and residential floor space. Joye and van den Berg (2011) note that these spatial limitations are particularly problematic in high-density urban environments, where biophilic interventions are most needed. In some cases, cultural and aesthetic preferences may conflict with biophilic design. Certain communities or stakeholders may view naturalistic elements as inconsistent with contemporary or traditional architectural styles. Browning, Ryan, and Clancy (2014) observe that resistance to biophilic aesthetics often stems from a lack of exposure or familiarity, rather than genuine incompatibility. Implementing biophilic design requires advanced engineering solutions, particularly for features such as living walls, natural ventilation systems, and water recycling infrastructure. Pallasmaa (2012) notes that the lack of expertise and technological readiness among project teams can hinder the successful execution of biophilic projects. Biophilic designs often involve ongoing maintenance, which can deter adoption. For example, the upkeep of green walls requires regular irrigation, pruning, and pest control, which may be viewed as burdensome. Wolverton et al. (1989) emphasize that such operational challenges discourage stakeholders from pursuing biophilic features, particularly in cost-sensitive projects. The challenges hindering the adoption of biophilic principles are multifaceted, ranging from economic and technical barriers to cultural and regulatory constraints. Addressing these challenges requires a coordinated effort involving education, policy reforms,

and innovative approaches to design and engineering. By overcoming these barriers, biophilic design can become a transformative force in architecture and urban planning.

5.0 Conclusion and Recommendations

The exploration of biophilic architecture has revealed its transformative potential in enhancing sustainability, human well-being, and innovative design practices while addressing critical challenges in modern urban environments. Overcoming these obstacles requires targeted efforts to integrate biophilic concepts into education, policy frameworks, and urban planning practices. To harness the full potential of biophilic architecture, the following recommendations are proposed. The governments should establish supportive policies and financial incentives, such as tax benefits and grants, to encourage the adoption of biophilic elements in construction and urban planning. Update building codes and zoning regulations to facilitate the integration of green infrastructure and innovative design practices. Incorporate biophilic principles into architectural curricula and professional training programs to ensure widespread knowledge among designers, planners, and builders. Conduct public awareness campaigns highlighting the economic, health, and environmental benefits of biophilic architecture. Foster collaboration among architects, urban planners, policymakers, and the private sector to create integrated biophilic solutions. Engage communities in the design and implementation process to ensure cultural and aesthetic compatibility with local preferences. Leverage advanced technologies, such as IoT and AI, to enhance the efficiency and functionality of biophilic systems, including energy management and green infrastructure maintenance. Expand the application of biophilic principles from individual buildings to entire neighborhoods and cities. Implement urban strategies, such as green corridors and biophilic public spaces, to maximize ecological and social benefits. Biophilic architecture offers a compelling vision for a future where human well-being, environmental sustainability, and design innovation coexist harmoniously. By addressing existing challenges and embracing opportunities for collaboration and technological advancement, this design philosophy can become a cornerstone of resilient and livable cities worldwide.

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