Review Article

Sustainable spaces - The evolution of biophilic design in modern architecture: A review

Abstract

In recent years, a resurgence of interest in reconnecting with "nature" has emerged, driven by its inherent benefits and the need to address societal and environmental challenges. However, the concept of "nature" remains ambiguous within architectural contexts, necessitating a nuanced approach. The theory of biophilia, rooted in the inherent human inclination towards life and lifelike processes, has led to the development of biophilic design principles. These principles aim to incorporate natural elements into built environments, enhancing human well-being and connection with nature. By integrating biophilic design into sustainable architecture, architects can address various challenges, from mitigating climate change to improving human health. Interdisciplinary collaboration and a nuanced understanding of biophilic design implications are essential for its successful implementation. Overall, biophilic design offers a compelling framework for creating sustainable and human-centric built environments, prioritizing elements that contribute effectively to human well-being and connection with nature. Through innovative design solutions, architects can address complex societal and environmental challenges, paving the way for a more sustainable future.

Keywords: Biophilia, Biophilic design, Sustainability, Architecture, Human well-being

Introduction

A recent upsurge in interest characterizes human-environment relations, marked by a renewed focus on re-establishing connections with the natural world. This trend is ostensibly driven by two primary factors: (1) a widespread recognition of the inherent advantages associated with exposure to natural environments, particularly regarding mental and physical health benefits, and (2) the intensifying need to address a confluence of societal and ecological challenges. However, a more comprehensive analysis is warranted to ensure the movement's efficacy.This renewed interest encompasses a spectrum of objectives, including enhancing health and well-being, promoting circularity, and building resilience. However, the concept of "nature" itself remains ambiguous and subject to debate, leading to questions regarding its efficacy within architectural contexts. Understanding "nature" requires grappling with its multifaceted nature—as both a concept and a tangible reality—while also acknowledging its contested and elusive qualities. Moreover, there's a need to critically examine the trend of literal greening in architecture, considering its potential as a marketing tool with limited impacts on broader social, economic, and environmental issues (Beck, 1999, p. 21). As such, navigating the complexities of conceptualizing and integrating "nature" into architectural practice necessitates a nuanced and critical approach.

Theory of biophilia to biophilic design

The term biophilia, coined by social psychologist Erich Fromm in 1964, encapsulates the concept of an inherent "love of life" within living organisms, encompassing their dual tendencies of preserving life against threats and fostering positive interactions. Despite its inception, biophilia theory remained relatively obscure until two decades later. Biologist Edward Wilson (1984) defined biophilia as the natural inclination towards life and lifelike processes. Wilson (1993) expanded on this with his biophilia hypothesis, suggesting that even as humanity transitioned to artificial environments, the emotional connection with life persisted. He described biophilia as an intrinsic emotional bond human have with other living organisms, rooted in hereditary traits and serving as a learning rule to understand nature.

Psycho-evolutionary theory, as proposed by Ulrich (1983), supports this notion, suggesting that certain emotional responses have evolved over time to adapt to modern societal challenges. Social ecologist Stephen Kellert (1993) identified nine values associated with biophilia, including utilitarian, aesthetic, and moral dimensions, broadening its scope beyond evolutionary psychology. This expansion mitigates biophilia's confinement to solely evolutionary significance, as noted by Joye and de Block (2011). Kellert's work underscores the importance of understanding the intricate relationship between humans and the natural environment, particularly evident in issues like biodiversity loss (Wilson, 1993).

Kellert (2008a) further emphasized biophilia as the inherent inclination of humans to affiliate with natural systems and processes, such as ecosystems, highlighting the shift in biophilia theory's focus towards exploring human-nature interactions since the 1990s.

At the outset of the 21st century, the concept of biophilia found its way into architectural discourse, shedding light on the emotional aspect of human yearning for engagement with the natural world within the built environment. This adaptation led to the proposal of biophilic design, aiming to offer design principles that cater to this innate longing for nature in architectural spaces (Almusaed, 2011; Cramer and Browning, 2008; Joye, 2007; Kellert, 2008b; Ryan *et al.,* 2014; Wilson, 2008). Biophilic design elucidates why certain buildings are esteemed for their superior connection with nature compared to others (Berkebile *et al.,* 2008). This connection with nature is believed to yield various benefits across different settings such as residential, work, educational, recreational, and medical environments (Abdelaal, 2019; Abdelaal and Soebarto, 2019; Gray and Birrell, 2014; Ha¨hn*et al.,* 2020; Jones, 2013; Mangone *et al.,* 2017; Peters and D'Penna, 2020; Totaforti, 2018; Wallmann-Sperlich *et al.,* 2019). Consequently, proponents argue that biophilic architecture contributes to sustainability by addressing the deficiency in human-nature interaction and promoting effective management of natural resources (Almusaed*et al.,* 2006; Hidalgo, 2014; Jiang *et al.,* 2020; Kayıhan, 2018; McMahan and Estes, 2015).

Origin

The genesis of biophilic design is rooted in various theories from environmental psychology, which extend beyond but encompass the theory of biophilia. These theories elucidate humanity's inherent inclination towards natural elements, attributing it to an instinctive yearning for "nature." They delve into the mechanisms through which contact with natural environments engenders both physical and mental well-being (Joye, 2007; Peters and

D’Penna, 2020; Ryan *et al.,* 2014; So¨derlund and Newman, 2015). In essence, these theoretical frameworks lay the groundwork for the evolution and conceptualization of biophilic design.

Timeline of Biophilic design

Biophilic design is a concept that integrates natural elements and processes into the built environment to create spaces that enhance the well-being and productivity of occupants. Here's a timeline of key events and developments in biophilic design:

1. Prehistoric Era: Indigenous communities worldwide demonstrate early biophilic design by integrating natural elements like wood and stone into their dwellings for optimal sunlight and ventilation (Ingold, 2000).

2. Ancient Civilizations (3000 BCE - 500 CE): Egyptians, Greeks, and Romans incorporate nature-inspired motifs such as gardens and water features into their architecture and urban planning (Bender, 2010).

3. Medieval and Renaissance Period (500 - 1600 CE): Gothic cathedrals and monastic gardens exemplify biophilic design with stained glass windows and botanical motifs (Hamburg, 1999).

4. 19th Century: The Romantic movement inspires nature-themed Arts and Crafts and Art Nouveau movements, with architects like Frank Lloyd Wright embracing organic forms (Calhoun, 2006).

5. 20th Century:

- 1920s-30s: Frank Lloyd Wright pioneers organic architecture with structures like Fallingwater (Pfeiffer, 2004).
- 1950s-70s: Modernists explore nature integration in urban design (Gissen, 2006).
- 1980s: E.O. Wilson introduces biophilia, spurring interest in biophilic design (Wilson, 1984).
- 1990s: Kellert's research advances understanding of biophilic design benefits (Kellert *et al.,* 2008).

6. 21st Century:

- Early 2000s: Green Building Movement emphasizes sustainability and biophilic design (Kibert, 2007).
- 2010s: Biophilic Cities Project promotes nature integration in urban planning (Beatley, 2011).
- Present: Biophilic design becomes mainstream in architecture, supported by evidence (Browning *et al.*, 2014).

Throughout this timeline (Figure1), numerous studies, research papers, and case studies have contributed to our understanding of biophilic design's impact on human health, well-being, and environmental sustainability. Additionally, architectural firms, interior designers, and urban planners have increasingly adopted biophilic design principles in their projects, further validating its importance in shaping healthier and more sustainable built environments.

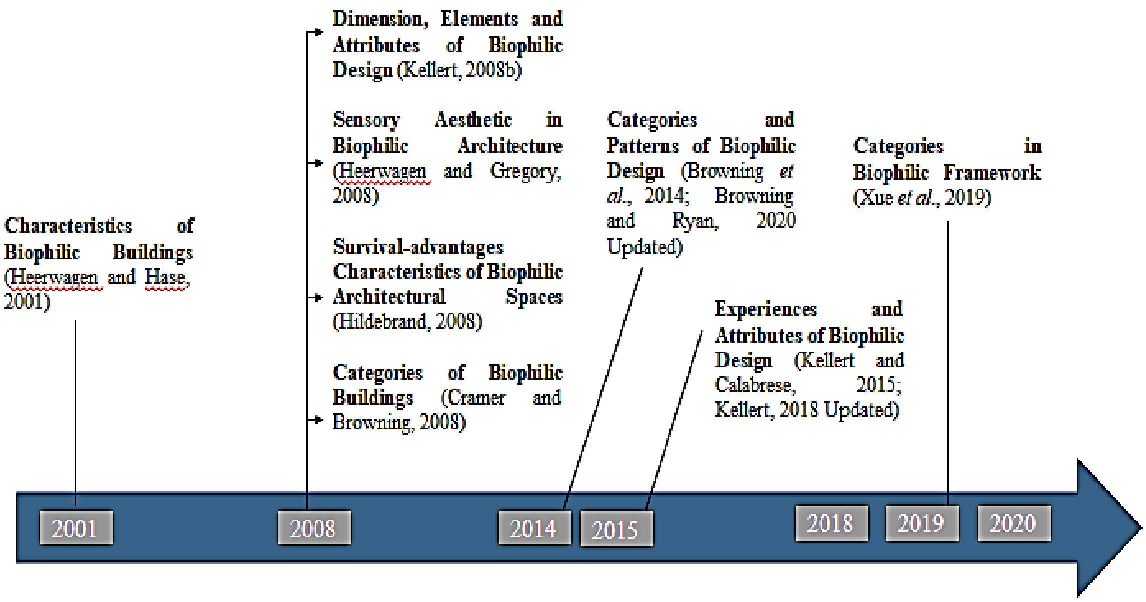

Figure1: Timeline of Biophilic Design

Defining biophilic design

Biophilic design involves integrating natural elements into architectural structures. This concept has evolved over time, with various experts proposing different methods to implement it. Early definitions, such as that by Heerwagen and Hase in 2001, emphasized the use of natural materials and aesthetics. Subsequently, Kellert and colleagues expanded on this by presenting a more structured framework encompassing diverse aspects of nature and their associated benefits.

Additional researchers, including Heerwagen, Gregory, Hildebrand, Cramer, and Browning, contributed their perspectives, examining the psychological effects of natural environments and how these insights could inform architectural design. Nonetheless, discrepancies exist among these approaches, with certain categories appearing vague and some ideas potentially lacking in their ability to truly foster a connection with nature.

To address these issues, it is crucial to explore how biophilic design can also promote sustainability in buildings. By identifying elements that benefit both nature and architectural structures, we can establish clearer guidelines for future architects to follow. The culmination of these efforts is evident in the recent publication "The Practice of Biophilic Design" authored by Stephen Kellert and Elizabeth Calabrese.This document outlines three experiences and 24 attributes of biophilic design, serving as an update on previous literature on the subject (Kellert, 2005 & 2008). The three experiences and 24 attributes are detailed in Table 1.

Table1. ExperiencesandattributesofBiophilicdesignby KellertandCalabrese

DirectExperienceofNature	**IndirectExperienceofNature**	**ExperienceofSpaceandPlace**
Light	ImagesofNature	Prospectandrefuge
Air	Naturalmaterials	Organizedcomplexity
Water	Naturalcolours	Integrationofpartstowholes
Plants	Simulatingnaturallightandair	Transitionalspaces
Animals	Naturalisticshapesandforms	Mobilityandway finding
Weather	Evokingnature	Culturalandecologicalattachment to place
Naturallandscapesandecosystems	Informationrichness	-
Fire	Age,changeandthepatinaof time	-
-	Naturalgeometries	-
-	Bio mimicry	-

Principles of Biophilic design

Biophilic design principles are rooted in the idea of incorporating elements of nature into the built environment to improve human well-being and connection with the natural world. Here are some key principles of biophilic design:

1. Environmental features: Direct contact with vegetation, in and around the built environment, is one of the most successful strategies for fostering human-nature connection in design (Kaplan, 1995; Kuo &Sulliva, 2001).
2. Natural shapes and forms: Natural environments show complexity at varying scales, from the vast openness of the sky to the dense complexity of the pattern of a single leaf (Kellert *et al.,* 2008). Large-scale detail in ornamentation and pattern is crafted in the sculptural ceiling plane and again in a smaller repeated scale of richness of detail at the metal stair railing (Browning *et al.,* 2014; Beatley, 2011).
3. Restorative patterns and processes: According to Dr. Stephen Kellert, human evolution and survival have always required managing highly sensuous and variable natural environments, particularly responding to sight, sound, smell, touch, and other sensory systems (Kellert & Wilson, 1993; Kellert, 2012). A central focal point offers reflection, stillness, and the chance to experience the soothing tones of wind chimes (Ulrich, 1984).
4. Light and space: This element of biophilic design focuses on the many diverse qualities of light and spatial relationships (Kellert, *et al.*, 2008). The heart of the library is its six-story atrium, which offers daylight for more than 80% of regularly occupied spaces (Browning *et al.,* 2014). The integration of abundant natural light in this cultural public space creates stimulating, dynamic, and sculptural forms (Beatley, 2011).
5. Place-based relationships: Considering place as a doorway to caring, this element focuses on connection to ecology and prominent biogeographical features (e.g., mountains, deserts, estuaries, rivers, and plants). This space of reflection, within a major healthcare facility, draws inspiration from the local Sonoran-desert; specifically, the colours and form of the native Ocotillo tree (Beatley, 2011; Kellert, *et al.,* 2008; Browning *et al.,* 2014).
6. Evolved human-nature relationships: Areas of refuge, a primary associated attribute, help to provide a safe place for retreat. Together, prospect and refuge in this space offer areas that improve concentration, attention, and perceived safety (refuge) (Browning *et al.,* 2014).

Framework of Biophilic Design

The framework of biophilic design encompasses various principles and elements aimed at integrating nature into the built environment to improve human well-being. Here's an overview of the framework along with references supporting each aspect:

1. Connection with Nature: Fostering a strong connection between occupants and the natural world through direct and indirect interactions with nature (Kellert *et al.,* 2008; Browning, *et al.,* 2014).
2. Natural Shapes and Forms: Incorporating organic shapes, patterns, and textures inspired by nature into architectural design (Beatley, 2011; Kellert *et al.,* 2008).
3. Sensory Engagement: Engaging all human senses through the use of natural materials, colors, textures, scents, and sounds (Kellert *et al.,* 2008; Browning, *et al.,* 2014).
4. Natural Light and Air: Maximizing access to natural light and ventilation to create healthier and more comfortable indoor environments.(Kellert *et al.,* 2008; Browning, *et al.,* 2014).
5. Biophilic Urban Planning: Incorporating biophilic design principles into urban planning and development to create green spaces, parks, and sustainable communities. (Beatley, 2011; Kellert *et al.,* 2008)

This framework provides a comprehensive approach to biophilic design, drawing from research in environmental psychology, biophilia, and sustainable design practices. Each principle is supported by scholarly literature and practical examples demonstrating its effectiveness in enhancing human well-being and connection to nature in the built environment.

Nature-health relationships:

Nature-health relationships involve intricate connections between exposure to natural environments and human well-being across cognitive, psychological, and physiological systems. Research conducted in controlled and real-world settings underscores the influence of surroundings on health.

i. Cognitive functionality and performance encompass mental abilities like agility, memory, problem-solving, and creativity. (Kellert *et al.,* 2008; van den Berg *et al.,* 2007). Strong connections with nature facilitate mental restoration, allowing cognitive functions to recover.

Engagement with natural settings provides opportunities for relaxation and mental rejuvenation, enhancing performance in focused tasks.

ii. Psychological health and well-being involve aspects like adaptability, attention, and emotional regulation. (Alcock *et al.*, 2013; Barton & Pretty, 2010; Hartig *et al.*, 2003; Hartig *et al.*, 1991). Experiences in natural environments contribute to greater emotional restoration compared to urban settings. Lower levels of tension, anxiety, and mood disturbance are reported among individuals exposed to nature.

iii. Physiological health and well-being include bodily responses related to various systems such as auditory, musculoskeletal, respiratory, and circadian rhythms. (Park *et al.*, 2009). Connections with nature elicit physiological responses promoting relaxation and stress reduction. Exposure to natural environments leads to muscle relaxation and reductions in blood pressure and stress hormone levels.Designing environments to manage physiological responses to stressors can facilitate the restoration of bodily resources. (Steg, 2007).

Biophilic design for sustainable architecture:

This segment delves into the integration of biophilic design principles with sustainable architecture, highlighting the challenges inherent in sustainable architectural endeavors and the benefits of incorporating biophilic elements into design. It examines the relationship between these design elements and overarching sustainability goals within architecture.

Since the 1990s, sustainability has become central in architectural discourse due to environmental challenges like resource depletion and climate change (Guy and Moore, 2005). Architects have explored various sustainable strategies, including energy-efficient technologies and the use of renewable materials. Sustainability in architecture is multifaceted, defying easy categorization (Guy and Moore, 2007).

The concept of 'sustainability' remains debated and ambiguous. The translation framework explores how practitioners interpret and apply sustainability in practice, aiming to bridge the gap between challenges and design intentions (Schro¨der, 2018).

Biophilic design offers strategies contributing to sustainability in architecture (Almusaed, 2011; Jiang *et al.*, 2020; Ryan and Browning, 2018). Researchers explore avenues such as enhancing resilience to climate change and aligning with Sustainable Development Goals

(Sharifi and Sabernejad, 2016). Experimental and empirical findings support integrating biophilic design principles into sustainable architecture.

To develop a systematic approach, we examine how biophilic design can contribute to sustainable architectural goals by aligning its benefits with specific challenges (Mossin *et al.*, 2018). We identify relevant Sustainable Development Goals (SDGs) and correlate biophilic design elements with architectural components.The architecture sector can address certain SDGs more effectively than others (WGBC, 2016). Nature-based design could potentially achieve various SDGs (Somarakis*et al.*, 2019). Table 2 illustrates the interconnectedness between biophilic design and sustainable architecture, denoting the degree of relevance to different SDGs.

Table2. Contributions by SDGs

The SDGs	**Contribution**
(***) 3. Good Health and Well-being 13. Climate Action	Heavily Supported
(**) 4. Quality Education 7. Affordable and Clean Energy 8. Decent Work and Economic Growth 9. Industries, Innovation and Infrastructure 11. Sustainable Cities and Communities 15. Life on Land 17. Partnerships for the Goals	Directly Take Advantage

(*) 1.No Poverty 2.Zero Hunger 5. Gender Equality 6. Clean Water and Sanitation 10. Reduces Inequalities 14. Life below Water 16. Peace and Justice Strong Institutions	Indirect Contributions

A comparative analysis of biophilic design and sustainable architecture reveals that the diverse benefits of biophilic design effectively tackle various challenges within sustainable architecture. Ranking contribution relevance shows that two Sustainable Development Goals (SDGs), 3 and 13, significantly benefit from biophilic design, with eight other SDGs (4, 7, 8, 9, 11, 12, 15, and 17) also deriving direct advantages. Meanwhile, seven SDGs (1, 2, 5, 6, 10, 14, and 16) generally benefit from biophilic design's indirect contributions. For instance, urban agriculture addresses Goal 1 (Zero Hunger), while water management practices reduce pollution for Goal 14 (Life below Water).

While the effects of biophilic design on these goals may be limited, exploring indirect benefits offers additional insights into sustainable architecture. These benefits may be measurable or not directly measurable, tangible or intangible, but they are interconnected. For example, the use of indigenous natural materials reduces construction costs (Goal 1) and contributes to material recycling (Goal 12). Similarly, reducing air pollution improves indoor air quality and environmental conditions, impacting health outcomes positively.

Certain priorities in biophilic design, such as air quality, daylight, plants, and landscape, emerge as crucial for achieving multiple sustainable goals. Given the urgency of addressing climate change, solutions with co-benefits for sustainable architecture are imperative. Further qualitative and quantitative research is needed to identify biophilic design strategies and guidelines for developing efficient solutions and supporting the enactment of criteria.

Biophilicdesign strategies

Biophilic design advocates propose various methods to integrate nature into our built environment, including creating parks and green spaces in cities, incorporating plants and natural materials indoors, applying biophilic design principles in specific buildings, and drawing inspiration from natural features like forests and water bodies. These approaches aim to improve well-being and productivity by fostering connections with nature (Beatley and Newman, 2013; Salingaros and Madsen, 2008; Wilson, 2008; McGee and Marshall-Baker, 2015; Lee and Park, 2018; Peters and D'Penna, 2020; Beatley, 2011; Gehl, 2010; Kellert *et al.*, 2008; Kellert *et al.*, 2012). Some strategies are derived from studying historical architecture, while others are based on natural attributes or patterns (Ramzy, 2015a; Browning *et al.*, 2014; Kellert, 2018).

Table 3 presents a compilation of biophilic design strategies utilized in architecture, outlining 18 elements within the proposed biophilic design framework. Designers are advised to possess interdisciplinary knowledge and select appropriate strategies based on their design goals and expected outcomes, considering potential physical and psychological reactions (Browning *et al.*, 2014). However, previous research often overlooked the diversity of biophilic design practices and failed to correlate their impacts with effective elements, hindering practical implementation.

Table3.*Biophilic Design Strategies*

S. No.	Biophilic element	Design Strategy
1.	Water	• Construct water features including rainfall spouts, aquaria, ponds, artificial wetlands, fountains, and water walls. • Having access to bodies of water in the form of rivers, streams, waterfalls, and oceans.(Browning *et al.*, 2014; Kellert, 2018)
2.	Air	• • Use vents movable windows, smaller buildings, etc. to increase natural ventilation. • Create the illusion of natural ventilation and airflow with the use of HVAC systems, movable windows, vents, airshafts, porches, and clerestories. (Browning*etal.*,2014; Gou*et al.*,2014;Kellert,2018)
3.	Daylight	• Use glass walls, clerestories, skylights, atriums, reflective materials and colors, etc. to let natural light in.

		• Create a space that mimics the spectral and ambient properties of natural light by installing various low-glare electric light sources, diffused ambient lighting on the walls and ceiling, and window treatments that preserve sunshine.(Browning *et al.*, 2014; Kellert, 2018)
4.	Plants	• Create indoor green walls and potted plants to bring greenery indoors. • Use green roofs, green walls and facades, expansive atria with park-like settings, green pockets, etc. to incorporate plants into buildings.(Chang and Chen, 2005; Kellert, 2018)
5.	Animals	• Construct areas for animals, such as aquariums and ponds. • Create habitats that are suited for animals, such as gardens, nest boxes, green walls or roofs, etc., to draw them in Kellert (2018)
6.	Landscape	• Create artificial ponds, meadows, prairies, woods, and other habitats on the sites. • Provide window views of natural landscapes such as forests, seascapes, and water motifs. • Create interior landscapes in atria, courtyards, entry areas, hallways, etc.(Kellert, 2018; Schweitzer *et al.*, 2004; Xue *et al.*, 2019)
7.	Weather	• Increase outdoor living spaces by adding movable windows, porches, balconies, terraces, courtyards, etc. • Increase knowledge of the weather by utilizing rainwater collection and spouts, transparent roofs, etc. • Copy the characteristics of the weather, such as temperature, humidity, airflow, sunshine, and barometric pressure. Kellert (2018)
8.	Time and Seasonal Changes	• Give views of the building facade and appearance that alter after being exposed to nature for an extended period of time. • Give views of the seasonal changes in the plants. Kellert (2018)
9.	Forms and Shapes	• Apply biomorphic design principles to architectural forms, structural systems, components, and interior spaces to emulate the outlines and patterns of living

		things. • Botanical or animal motifs, shells, spirals, eggs, ovals, tubular forms, arches, vaults, domes, etc. are examples of biomorphic elements.(Browning *et al.*, 2014; Joye and Loocke, 2007; Kellert, 2008b, 2018)
10.	Patterns and Geometries	• Use scales, hierarchically arranged ratios, and fractals in your designs. • Apply the Golden Ratio (1:1.618) or the Fibonacci series (0, 1, 1, 2, 3, 5, 8, 13, 21, 34). • Select the intermediate ratio of 1:1.35 to 1.75.(Browning *et al*., 2014; Md Rian and Sassone, 2014; Ramzy, 2015a)
11.	Mechanisms	• Use bio mimicry, or learning from other species to suit functional needs. For example, termites and spiders have been shown to be efficient climate controllers and to have strong structural construction materials. (Kellert, 2018; Yuan *et al.*, 2017)
12.	Images	• Display images of landscapes, water, plants, animals, or geological elements in paintings, photos, films, and textiles. • Images of nature should feature a wide range of animals, scenery, and human experiences surviving in the wild. (Browning *et al*., 2014; Kellert, 2018)
13.	Materials, Texture, and Colour	• Use organic materials like wood, bamboo, rock, stone, clay, etc.; • Take into account textures other than just materials, such color, light, and sound. • Employ earthy hues like blue, green, and other natural hues.(Kellert, 2018; Tsunetsuguet *al*., 2007)
14.	Prospect and Refuge	• Imagine areas that have two complimentary features: broad perspectives or vistas and enclosed, secure environments or shelters (refuge). • Created indoor and outdoor experiences using balconies, courtyards, colonnades, and window views • Employ controlled lighting to create areas that have refuge-like qualities(Bloomer, 2008; Browning *et al.*, 2014; Kellert, 2018)
15.	Complexity and Order	• Arrange diversity and rich details in a systematic way. • Take into account organic shapes,

		patterns, and geometries, particularly when it comes to exposed building features, facades, and structures. • Select materials with distinct hues and textures, or thoughtfully arrange plants in different combinations and placements.(Browning *et al.*, 2014; Kellert, 2018)
16.	Entícement (Peril and Mystery)	• Use cantilevers, infinity edges, transparent facades, routes under or over water, scenes defying gravity, etc. to create a sense of "peril." • Use twisting routes, translucent materials, undetectable sound sources, curved or obscured edges, etc. to create "mystery." (Browning *et al.*, 2014; Kellert, 2018)
17.	Connection to Place	• Use native plant types and materials, and offer vistas of notable landmarks, landscapes, waterscapes, and geological formations. • Use landscape elements, such as savanna-like settings, to define building forms or specific landscape design(Kellert, 2008b, 2018)
18.	Connection of Spaces	• When designing transitional spaces like porches, patios, balconies, courtyards, pavilions, gardens, entry areas, foyers, atria, etc., consider the links between the interior and external. • Take into account movement in areas such as hallways, staircases, high-level glass elevators, etc. (Kellert,2008b,2018)

Moreover, incorporating these elements requires knowledge from various architectural subfields, including materiality, tectonics, mechanical systems, and mobility. Unfortunately, these subfields are rarely integrated in biophilic design studies. Therefore, it is crucial to align design objectives with specific biophilic design elements and involve specialists from relevant fields in the development of applicable guidelines.

Recent Trends:

Biophilic design has evolved beyond visual elements to incorporate auditory and olfactory experiences, recognizing nature's multisensory nature (Browning et al., 2014; Kellert, 2018).

Fragrant plants and sounds of nature, such as bird songs and water sounds, have been found to be highly restorative (Browning *et al.*, 2014; Kellert, 2018).

While extensive research has focused on individual elements of biophilic design, there has been limited investigation into their combinations. The first longitudinal study on a biophilic-designed space incorporating various elements is underway in Australia, showing promising results in reducing stress, enhancing productivity, and improving well-being (Browning *et al.*, 2014; Kellert, 2018).

Biophilic design aligns with low-impact environmental design to create restorative environmental buildings. It is integrated into green building rating systems like the Living Building Challenge, which emphasizes biophilic environments as a key imperative. Additionally, the WELL Building Standard, launched in 2014, includes mandatory and optional areas dedicated to biophilic design, focusing on human health and well-being (Browning *et al.*, 2014).

Terrapin Bright Green has synthesized biophilic design concepts into 14 patterns to aid designers in creating biophilic spaces. While biophilic design doesn't necessarily require a rating system, integrating it into such systems can shift industry conversations and promote its adoption. Many buildings may already exhibit biophilic design properties, but formal recognition through rating systems like WELL and Living Building Challenge can accelerate its adoption and positively influence the building industry (Browning *et al.*, 2014).

Conclusion:

The concept of biophilic design represents a pivotal shift in architectural thinking, recognizing the profound impact of nature on human well-being and the environment. By embracing biophilic principles, architects have the opportunity to create spaces that not only support physical health and psychological well-being but also contribute to broader sustainability goals. The integration of natural elements, such as greenery, natural light, and water features, not only enhances the aesthetic appeal of buildings but also fosters a deeper connection with the natural world.

Moreover, biophilic design offers a holistic approach to sustainability, addressing not only environmental concerns but also social and economic dimensions. By promoting human-nature interactions, biophilic design can help alleviate stress, improve productivity, and foster a sense of community among building occupants. Additionally, biophilic elements can contribute to energy efficiency, biodiversity conservation, and the preservation of natural resources, thereby advancing sustainable development objectives.

However, the successful implementation of biophilic design requires collaboration across disciplines, including architecture, psychology, ecology, and urban planning. Architects must consider the specific needs and preferences of diverse user groups and incorporate biophilic elements in a thoughtful and meaningful way. Furthermore, ongoing research and evaluation are essential to assess the effectiveness of biophilic design strategies and refine best practices over time.

In conclusion, biophilic design represents a promising approach to creating healthy, sustainable, and resilient built environments. By harnessing the restorative power of nature, architects can design spaces that not only enhance human well-being but also contribute to the preservation and restoration of the natural world. As we continue to confront pressing environmental and social challenges, biophilic design offers a pathway towards a more harmonious relationship between people and the planet.

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