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**BIOPHILIC DESIGN STRATEGIES TO
ENHANCE PRODUCTIVITY AND WELL-BEING
IN OFFICE SPACES**

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Master's Thesis

Supervisor

Asst. Prof. Dr. Erine ONBAY

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XXXXXXXXXX

DEDICATION

Dedicate to the Almighty, Allah, whose guidance always illuminated my path during this journey and all my life.

I would thank the Republic of TÜRKİYE, the country that embrace me with open arms and enrich my growth throughout my academic journey.

I want to thank my supervisors, Dr. Erine ONBAY and Dr. Can UZUN, I won't forget your continued support and valuable advice.

The special gratitude will be to my Family,

To my mother, Melek, my haven and the light of my life, words fail to capture the depth of my feelings for you. You believed in me, held me in your heart, prayed for me, and stood by me in every step, nothing can repay your virtues.

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To all my friends who color my life with special moments and stand by me in the hard times.

To all the people who left a special mark on my soul.

ABSTRACT

BIOPHILIC DESIGN STRATEGIES TO ENHANCE PRODUCTIVITY AND WELL-BEING IN OFFICE SPACES

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Interacting with nature is an essential factor for human health and overall **well-being**; urbanism and new design approaches in the last years have led people to spend more than 90% of their time indoors and move away from the natural environment, which caused them a lot of stressful environments, psychological, physical, and psychological problems.

Work plays a significant role in people's lives at this time. Especially, **offices** are now considered the main reason behind letting individuals find themselves within enclosed workplaces, resulting in their being disconnected from nature throughout the weekdays and for a long time.

Biophilic design is rooted in the concept of **sustainability** and enhancing the beneficial impacts of nature within built environments and quality of life. It aims to decrease the issues caused by modern life that humans face within enclosed spaces, especially workplaces.

The study objective is to consider the strategies that integrate human psychology with nature through biophilic design and how its principles can be applied in office spaces to meet human needs.

The study utilized qualitative research methods document analysis and descriptive analysis. It focused on examining office spaces with significant biophilic design elements, as identified by Browning et al.

Keywords: Biophilia, Biophilic Design, Sustainability, Well-being, Offices.

ÖZET

BİYOİLİK TASARIM STRATEJİLERİYLE OFİS ALANLARINDA VERİMLİLİK VE İYİ OLUŞUN ARTIRILMASI

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Doğa ile etkileşim, insan sağlığı ve genel **iyi oluş** için önemli bir faktördür; son yıllarda kentleşme ve yeni tasarım yaklaşımları, insanların zamanlarının %90'ından fazlasını kapalı alanlarda geçirmelerine ve doğal çevreden uzaklaşmalarına neden olmuştur, bu da onlara birçok stresli ortam, psikolojik, fiziksel ve ruhsal problemler yaratmıştır.

Çalışma, insanların yaşamlarında önemli bir rol oynar. Özellikle, **ofisler** artık bireylerin kendilerini kapalı iş yerlerinde bulmalarının ana nedeni olarak kabul edilir, bu da onların hafta boyunca ve uzun süreler boyunca doğadan kopuk olmalarına yol açar.

Biyofilik tasarım, sürdürülebilirlik kavramına ve yapılandırılmış çevrelerde doğanın faydalı etkilerini ve yaşam kalitesini artırmaya dayanır. Modern yaşamın neden olduğu sorunları, özellikle iş yerlerinde, azaltmayı amaçlar.

Çalışmanın amacı, biyofilik tasarım yoluyla insan psikolojisini doğa ile bütünleştiren stratejileri ve bu prensiplerin ofis alanlarında insan ihtiyaçlarını karşılamak için nasıl uygulanabileceğini incelemektir.

Çalışmada nitel araştırma yöntemleri, doküman analizi ve betimsel analiz kullanılmıştır. Browning ve arkadaşları tarafından tanımlanan önemli biyofilik tasarım unsurlarına sahip ofis alanlarının incelenmesine odaklanmıştır.

Anahtar Kelimeler: Biyofili, Biyofilik Tasarım, Sürdürülebilirlik, İyi Oluş, Ofisler.

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ABBREVIATIONS

ART	:	Attention Restoration Theory
SRT	:	Stress Reduction Theory
BDE	:	Biophilic Design Element
WHO	:	World Health Organization
SDG	:	Sustainable Development Goal
DB	:	Decibel
LX	:	Luminous Flux
NYC	:	New York City
GRIHA	:	Green Rating For Integrated Habitat Assessment
HVLS	:	High Volume Low Speed
LEED	:	Leadership In Energy And Environmental Design

1. INTRODUCTION

Since the dawn of existence, human beings have been always connected to nature as an integral universe component. Various researchers have emphasized the positive effects of engaging with nature on human health, as well as psychological and physical well-being [1]. Due to industrialization, the growth of the human population and urbanization resulted in replacing natural places with artificial environments. Unfortunately, the design approaches adopted in crafting the modern built environment have contributed to environmental degradation and the separation of humans from the natural realm. This degradation destroys the balance of nature and harmfully impacts human health and psychology [2].

In response to the circumstances observed in the late 20th century, considering, and planning a pragmatic attitude towards nature was dismissed. Instead, design methodologies that were attuned to nature's needs were developed. While other methods consider the sustainability of nature and resources, the biophilic design explicitly emphasizes the sustainability of the link between people and nature in constructed spaces. Kellert [103] has classified it as the "missing link in sustainable design," and it has emerged as a new field of research.

Office spaces created with a modern approach to the built environment typically prioritize utility over the psychological and mental well-being of the workers. Office environments characterized by distinct borders result in workers feeling alienated from the natural environment and spending extended periods in enclosed areas. The psychological troubles arising from extended durations spent in such environments and the physical problems caused by insufficient indoor ventilation and climate control conditions contribute to stress-related problems.

Thus, it is widely accepted that office environments prioritizing the sustainability of the human-nature connection can positively impact employees' well-being and psychological requirements.

This study investigates potential design strategies that consider both nature and human psychology by incorporating biophilic design features. Additionally, the study attempts to determine how these biophilic design applications might be implemented in office spaces to meet current requirements.

Research has shown that nature benefits humans, and "biophilic design" has arisen as a design strategy for incorporating nature into the areas people live in [47]. According to Kellert's books [40] [14], the biophilic design has a good impact by enrolling natural systems in the design approach and positively influencing physical and emotional well-being [14]. Biophilic design decreases stress, anger, and anxiety. It boosts productivity and creativity, promotes well-being, and speeds recovery [79]. According to Kellert and Calabrese [103], biophilic design improves humans' enjoyment, motivation, focus, and attention span. Biophilic design in buildings and living places enhances the connection between individuals and the natural environment.

According to research conducted by the Environmental Protection Agency, almost 90% of human existence is spent in constructed surroundings, with workplaces accounting for one-third of these built environments. Due to these factors, offices are now constructed based on biophilic design concepts. The research stressed that individuals exhibit higher productivity levels in buildings that incorporate natural elements. Additionally, previous studies [104] have underscored the positive impact of biophilic design principles on individuals' connection to nature in both buildings and living spaces. Implementing biophilic design components in office spaces enhances staff performance and productivity while decreasing workplace stress [6].

This study will explain the concept of biophilic design indicating the biophilia hypothesis and then examine its principles. The evaluation of office structures will be based on these factors. Next, we will examine the concept of office buildings, including their design and spatial organization, and the health issues that office workers commonly encounter. The report will discuss the outcomes of analyzing office structures using biophilic design criteria. The research will examine office structures within the strategy of biophilic design. Ultimately, suggestions will be created to facilitate the linking of the biophilic design features into office spaces.

The First Chapter of the thesis will cover the purpose, scope, and methodology.

The Second Chapter will focus on the historical process of the human-nature relationship, and the perspective of this relation in architecture. These aspects will form the foundation of the "Biophilia Hypothesis." Furthermore, the thesis will include principles of nature-friendly architectural design to establish a contextual framework.

Then will focus deeply on the concept of biophilia, which forms the backbone of the thesis, and the evaluation of the biophilic design idea for the built environment, defined as "biophilic design." Then it will discuss the relationship between sustainability and biophilic design approaches and the roles of architects in reaching the 17 sustainability development goals through the biophilic design elements.

The Third Chapter will discuss the definition of office spaces and their development process. Then, it will discuss the ergonomic aspects of offices, the problems, and the psychological effects of using offices. Finally, the biophilic design approach will be reduced to office spaces, and the importance and benefits of biophilic design for offices will be addressed.

In the Fourth Chapter, we will examine two office structures (Titan integrity campus and Amazon spheres) predicted to contain biophilic design elements selected within the study. The evaluation of the 15 biophilic design principles application identified by Browning et al will be conducted. The biophilic design characteristics of the structures will be determined by visualizing the presence of biophilic qualities with photographs of office spaces that interact with nature in the selected structures. The data obtained from the document analysis and descriptive analysis will be summarized and tabulated in the findings section.

1.1 STATEMENT OF THE PROBLEM

In the last 20 years, urbanization emerged due to rapid population growth and industrialization, replacing natural areas with human-made spaces. Many design approaches shaped the modern built environment which led to environmental degradation and caused separation of humans from nature.

Working life, especially in closed offices, nowadays constitutes a central part of individuals' daily leisure; the design of the office also plays a massive role in the work environment. where the needs and expectations of the employees are not successfully addressed, which leads to many negative impacts on human psychology, productivity, and well-being.

People frequently suffer psychological and physical health challenges stemming from the workplace. Factors like heavy workloads, continual pressures, and hectic times cause various health issues. Besides physical diseases, employees living with stress every day may also contend with a spectrum of psychological problems, including depression, anxiety, burnout,

sleep quality, digestive complications, muscular tension, headaches, and cardiovascular disorders [33].

Biophilia and healing design become a permanent source of inspiration for architecture and encourage the integration of nature in the built environment to enhance humans' psychological and physiological health, and emotional and cognitive functions for the healing process [5].

Biophilic design through the studies proves that it affects not only sick people but also children, employees, elderly people, and those with disabilities, etc.

It was noticeable that the relationship between nature and humans is effective in enhancing mood and productivity, in addition to including Biophilic design elements in interior spaces to improve people's physical and mental health [5].

1.2 RESEARCH OBJECTIVES

- a. Analyse workspace environments and assess how the biophilic design strategies affect employee well-being and productivity, considering the biophilic 15 principles.
- b. Study the biophilic design elements that can be implemented in office spaces to enhance psychological and physical health.
- c. Understand the link between sustainability and biophilic design and how its elements can support the challenges of applying sustainable architecture to reach sustainable development goals.
- d. Raise awareness of the use of biophilic design in offices to avoid physiological and psychological disorders and other office health-related issues.

1.3 RESEARCH QUESTIONS

- a. What are the contributions of direct and indirect contact with nature in the built environment to human health? How do the employees receive and be affected by the integration of the biophilic design elements into their workplace environment?
- b. Does implementing biophilic design patterns create more environmentally sustainable office space?

1.4 RESEARCH METHODOLOGY

This study aims to investigate office buildings through the patterns of biophilic design. This involves conducting a literature review to synthesize existing knowledge and establish a theoretical framework. At the same time, qualitative research methods will address research questions and propose solutions within this framework.

1.4.1 Literature Review and Theoretical Framework

Literature Review: An integrated literature review on biophilic design principles and Office design and application of biophilic design in office buildings will be conducted. This will involve gathering relevant scholarly articles, books, and reports from academic databases. Key themes and concepts will be identified to establish a theoretical framework.

Theoretical Framework: The framework will guide the interpretation of qualitative findings. It will provide a lens through which to analyze and understand the relationship between biophilic design and office environments.

1.4.2 Qualitative Method

The qualitative method will be conducted by comparative analysis by Incorporation of Visual Documentation and photographs to enhance understanding and illustrate critical findings.

The research process, including data collection procedures and analysis techniques, will be thoroughly documented.

Qualitative findings will be presented using tables, figures, and visual materials to support interpretation and enhance readability.

It was observed that overseas examples were richer in biophilic aspects compared to examples from our country. Therefore, the study did not include a sample office building from our country.

Two awarded international office buildings (Titan Integrity Campus in India and Amazon Spheres in US) were selected for the field study, will be evaluated according to the 15 biophilic design criteria prepared by Browning et al [16] [15] to answer the questions mentioned above.

2. BIOPHILIA AND BIOPHILIC DESIGN

2.1 HISTORY OF HUMAN-NATURE RELATIONSHIP NATURE

The evolution of Earth spans approximately 4.5 billion years. Human fossils from as early as 6.5 million years ago have been discovered, and scientists commonly acknowledge that our species reached its current physical form approximately 40,000 years ago. Civilizations' ecological and cultural development can be categorized into five distinct periods: "Early Hunter-Gatherer, Advanced Hunter-Gatherer, Agriculture, Industry, and Modern Day [96].

During the Early Hunter-Gatherer period, people utilized natural resources such as stones and sticks, which served essential purposes such as hunting and clothing. Migration to more regions facilitated improved acclimatization to environmental obstacles, resulting in the development of new mechanisms of adaptability [96].

During the Advanced Hunter-Gatherer period, the intentional utilization of fire altered dietary patterns and enhanced self-defense. Humans commenced comprehending the advantages of nature and undertook investigations to ascertain sources of sustenance, water, and therapeutic flora. Collaborative hunting expeditions improved communication abilities and established the foundation for cultural advancement [96].

During the Agricultural period, humans transitioned to agriculture and animal husbandry, actively modifying their surroundings to accommodate their needs. As populations expanded, food was scarce, which led to the creation of equipment and technologies to address the increased demands. The practice of agriculture resulted in the development of diverse occupations, the division of labor, and the introduction of the concept of currency. As humans sought to gain from nature, they believed they could control it through technology and resource exploitation, leading to social hierarchies and environmental catastrophes [96].

The Industrial Revolution was characterized by the extensive utilization of steam engines, coal, and oil, resulting in the substitution of human labor with machinery and the automation of manufacturing methods. Consequently, there was a rise in productivity accompanied by a decrease in the need for labor, which led to the migration of workers to urban areas. As people gained control over natural circumstances, they started perceiving themselves as dominators of nature, resulting in the exploitation and mistreatment of the environment.

Ecological equilibrium has been upset by waste disposal, overutilization of natural resources, urbanization, and population expansion, resulting in a preference for human interests and posing a threat to many species [96].

In the late 20th century, there was a shift towards adopting a holistic perspective rather than a reductionist approach. The holistic approach refers to the simultaneous domination of all interconnected components in nature, as a potential impact on nature can result in several reactions. Some social and environmental scientists contend that to avert ecological catastrophes, it is imperative to alter society's thinking and cultivate environmental consciousness in individuals from an early age. In the 21st century, humanity has started to be aware of its connection to the natural world and activate the forgotten aspects [96].

Architecture throughout history proves its ability to impact a person's physiological and psychological moods originates from our innate biophilic affinity for nature. The idea of biophilic design in architecture has been evident from the past to the present, both consciously and instinctively. It is exhibited through many elements, such as forms, patterns, materials, symbols, figures, and voids, which elicit similar responses to nature. As humans have gradually distanced themselves from natural surroundings, they have incorporated aspects that include nature into the construction in response to the lack of natural elements. Biophilic design, based on the idea that humans have an inherent love for beauty, asserts that people cannot go too far from the natural world and must establish primal connections with nature, as they did in the past, in order to maintain their internal well-being [96].

2.2 HISTORICAL PERSPECTIVES ON THE RELATIONSHIP BETWEEN NATURE AND ARCHITECTURE

The connection between nature and architecture has deep historical roots, evident in various notable examples in Figure 2.1. One such example is the renowned Hanging Gardens of Babylon, believed to be an extraordinary feat of classical antiquity. Situated near a water source, these gardens were adorned with diverse trees, arranged in terraced gardens.

Additionally, incorporating natural landscapes into architectural designs became popular among affluent families, like the Italian Renaissance gardens of Villa di Castello as seen in Figure 2.1. Landscape architecture continued to evolve throughout the 19th century, with figures like Andrew Jackson Downing promoting the integration of verandas to connect

residences with the surrounding natural environment. Furthermore, architects drew inspiration from Gothic architecture, advocating for the use of natural forms in structural design, as evidenced in works by Eugène Viollet-le-Duc, Victor Horta's Hôtel Tassel, Antoni Gaudí's Casa Batlló, among others [106].

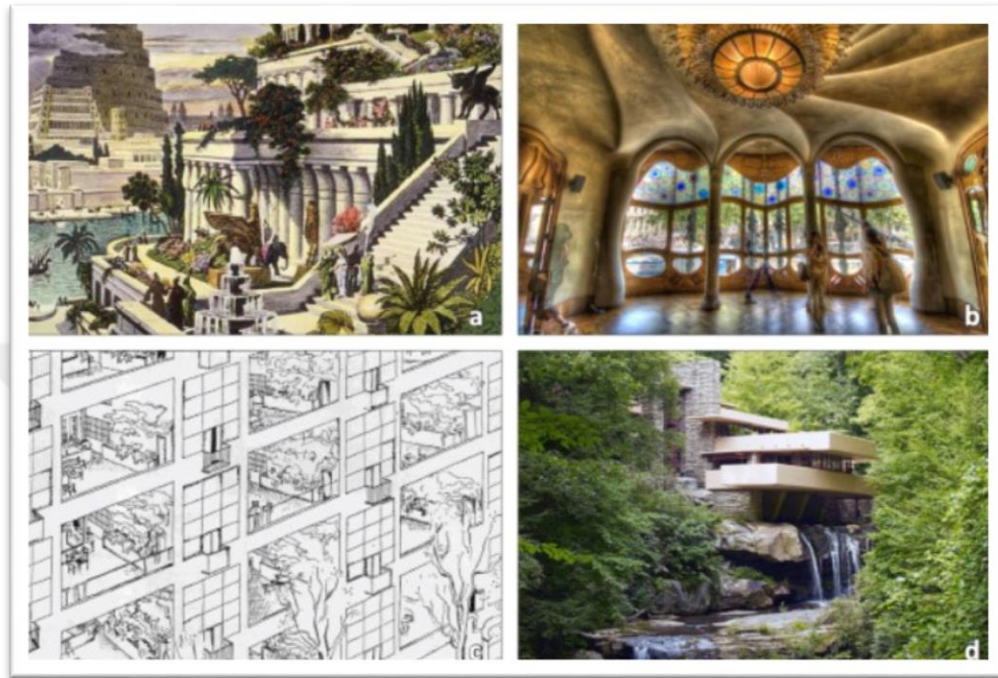


Figure 2.1: Instances Of Including Natural Elements Into Architectural Designs. (A) The Hanging Garden Of Babylon (B) Casa Batllo, By Antoni Gaudí; (C) Immeubles-Villas, By Le Corbusier; (D) Fallingwater, By Frank Lloyd Wright.

In current discussions on architecture, architects have broadened their investigation of integrating with the natural environment by adopting various methodologies. Leberecht Migge supported the idea of including gardens that provide food in social housing schemes, while Le Corbusier suggested including private gardens in his conceptual design for Immeubles-villas in Figure 2.1. Numerous prominent contemporary architectural projects embody this principle of harmonious living with the natural environment. Fallingwater, designed by Frank Lloyd Wright, harmoniously blends with its natural environment, specifically through its cantilevered terraces that extend horizontally into the terrain. Also, the Farnsworth House by Ludwig Mies van der Rohe establishes a strong relationship with its surroundings by putting many glass walls and intricate structural components.

An increasing recognition of the ecological effects of modern ways of living sparked a heightened environmental consciousness in the 1960s. Ian McHarg, a landscape architect,

promoted an ecological method in urban planning, which involved conducting thorough assessments of land, climate, and water systems. Simultaneously, the cutting-edge architectural movement of that time, exemplified by individuals such as Mario Bellini, Alberto Rosselli, and Archizoom, contemplated the harmful consequences of contemporary building practices on the environment through innovative and forward-thinking endeavors. Although many of these efforts were primarily aimed toward exploration, they significantly influenced social views on the main connection between people and the natural environment [106].

2.3 BIOPHILIA HYPOTHESIS

Interacting with nature is a psychological need for humans. It has been observed that human-nature interaction weakened with the Industrial Revolution. With the influence of urbanization, humans increasingly disconnected from nature and began to spend most of their lives in built environments isolated from the natural environment. Urban life leaves adverse psychological, physical, and cognitive effects on people [5].

Instead of humans returning to nature, "biophilic design" has been adopted to restructure and sustain human-nature interaction in built environments. In this section, the phenomenon of "biophilic design," which will be the primary purpose of the study as a field related to sustainable, ecological, and green architectural approaches shaping contemporary architecture understanding, will be examined.

2.3.1 The Concept of Biophilia

To understand the concept of human-nature connection in architectural contexts, it is essential to start by identifying what "biophilia" means. After that, theories explaining why people prefer specific environments and assessing the biophilia concept's validity will be examined. The term "biophilia," which was coined by Erich Fromm in 1964 by combining the prefix "bio" (life) with the suffix "philia" (love, affinity), refers to a "psychological obsession with love for life and living systems, being attracted by living and vital things." [1].

Ecologist and sociologist Edward O. Wilson, who developed the concept of biophilia in the 1980s, describes it as an "innate tendency to focus on life and living processes" [2] and as

"the innate closeness of humans to other forms of life, awakened through a mix of pleasure, a sense of security, or enchantment mixed with disgust depending on conditions." [2].

2.3.2 Theories Supporting the Importance of Biophilia in the Built Environment

Since human evolution, individuals have continuously adapted their surroundings to suit their needs and interests, taking inspiration from the natural world. This connection with nature has influenced human behavior and helped address existential challenges. [1] This section of the study will explore the theories underpinning biophilia, exploring its significance.

The landscape is an integral part of the ecological environment. Considering that landscape significantly impacts health, it affects more than heritage, or a site preserved for its aesthetic appeal; it also embodies the concept of the right to landscape, which is fundamentally connected to the well-being of current and future generations [3].

Theories related to landscape preferences can be examined in two categories based on evolutionary and cultural paradigms:

2.3.2.1 Theories Based on psycho-evolutionary principles

a. Attention Restoration Theory (ART)

Many environmental psychologists contend that people can obtain psychological wellness through engagement with natural surroundings. In terms of gaining places offering opportunities for rest, unwinding, and healing, psychological fatigue arises from prolonged office hours without breaks, impacting mental capabilities and leading to burnout. Continuous focus on a task can lead to mental fatigue.

According to the theory, natural environments, such as clouds moving in the sky, gardens, leaves, voices, or water elements, can potentially increase a person's level of attention. This theory, which emerged to examine the benefits provided by nature, claims that spending time in nature or even looking at a natural landscape can enhance a person's quality of concentration and raise the brain's ability to focus more efficiently [3].

Providing a sense of immersion in the environment, being far away from routine activities in the offices in some parts, and the existence of elements that capture attention can have a therapeutic effect on supporting individuals' wellness in the workplace [3].

b. Stress Reduction Theory (SRT)

According to this theory, the unique beauty of natural environments positively affects humans; extended time spent in enclosed spaces like hospitals and offices can induce stress. Interacting with nature and natural landscapes can alleviate physical and mental discomfort [5].

The presence of natural elements or nature-inspired features in office buildings reduces the stress levels of employees and positively affects employee health [6].

Adding natural elements to office spaces reduces stress and boosts employee health. A study in Norway found that employees in offices without windows made up for the lack of natural views by adding indoor plants and pictures of natural scenes to their work areas. Also, using green plants and artificial daylight indoors helps reduce health problems for office workers. Experiments in labs, looking at how bodies react in different work environments, consistently found that having natural scenery and plants around led to the lowest stress levels [7].

2.3.2.2 Theories based on nature and environment principles.

a . Fractal Theory

Fractals are complex geometric patterns that repeat at different scales, creating intricate and visually appealing designs. Architects often incorporate fractal patterns into building facades, interiors, and landscaping to enhance the aesthetic appeal of spaces. These fractal-inspired designs can evoke a sense of beauty, harmony, and natural order, positively impacting occupants' moods and perceptions of space [8].

Research suggests that exposure to fractal patterns can have cognitive benefits, such as improved focus, stress reduction, and creative thinking.

In architectural design, incorporating fractal elements into interior spaces, furnishings, and artworks can stimulate occupant's minds and give a sense of engagement and inspiration. By

applying fractal theory, architects can create environments that support occupants' cognitive function and emotional well-being [8].

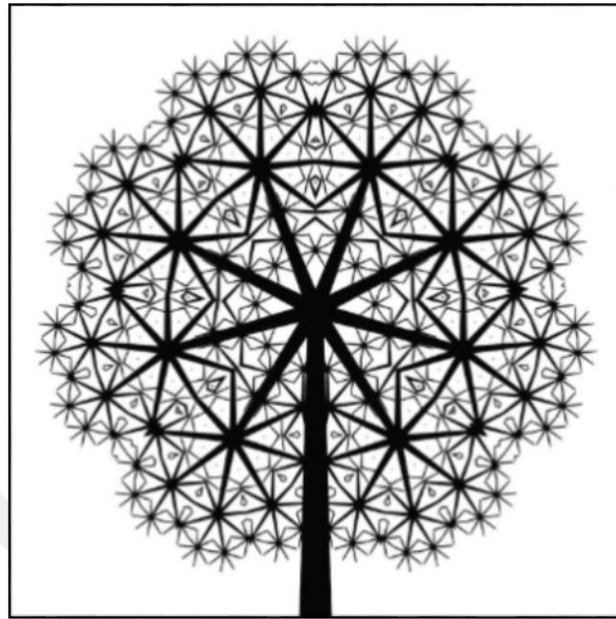


Figure 2.2: Fractal Tree, Geometry Art, Fractals [25].

b. Habitat theory

discusses how humans feel and respond to natural environments based on their needs. Some researchers believe that people naturally prefer safe environments that offer good chances of survival. They find places like savannas appealing because they provide hiding spots during danger and allow for easy observation of surroundings.

The "Savanna Hypothesis" suggests that humans, due to their evolutionary history, like environments resembling savannas. These environments are believed to have contributed to human survival and quality of life throughout evolution. Savanna-like environments have specific characteristics such as scattered trees for shelter, diverse resources for nutrition, open spaces for visibility and movement, scattered water sources, different terrains for observation, and open skies [9].



Figure 2.3: Savanna Woodland At Gumriak [24].

c. Biophilia Hypothesis

In the 1980s, ecologist Wilson emphasized the significance of nature for humans, suggesting that both rational and irrational psychological mechanisms influence our interactions with nature. He proposed a hypothesis regarding how humans perceive, need, and behave towards nature. Wilson's theory suggests that our connection with nature is not solely based on rational thinking but also involves irrational psychological factors. This implies that our relationship with nature is too complex to be fully understood through logic alone [10].

Wilson suggests that the gaps in human-nature interactions can lead to Nemours health problems, emphasizing the importance of maintaining a link with nature for overall well-being.

In his book, Wilson emphasizes that combining humans' love for nature with environmental awareness and conservation efforts can lead to solutions. He expresses his profound admiration for life and natural systems, creating the foundation of the biophilia hypothesis. In addition, Wilson suggests that from the dawn of humans interacting with their environment, mental characteristics that influence perception and senses, such as focus and emotional affiliation, have developed [10].

Despite today's modern world being filled with artificial objects, structures, and environments, humans maintain an enduring relationship with nature driven by phylogenetic memory inherited from ancestors. Wilson suggests that this tendency, known as biophilia, is inherent in human biological codes [10].

2.4 BIOPHILIC DESIGN

Biophilic design, born out of a desire to approach nature, is also known as "life-friendly design" [11], which states that humans adapt better to environments where nature predominates. People feel better in places where sunlight is abundant, animals are present, and there are trees, flowers, birds, flowing water, etc. Biophilic design shapes structures accordingly [12].

Biophilic design is also known as healing design. It integrates natural systems and processes into built environments to enhance and support individual and community health. Additionally, biophilic design provides people with breathable biological living spaces [13].

Biophilic design focuses on humans, aiming to bring natural elements to architectural spaces to improve human health and well-being. Sustainable design indirectly contributes to minimizing damage to the built environment by sustaining the human-nature interaction in the built environment. Therefore, Kellert describes biophilic design as the "missing link of sustainable design" and states that it is related to sustainable design due to natural lighting, natural materials, and clean air. Biologically harmless materials and renewable natural energy sources are utilized in biophilic design, aiming for a comfortable lifestyle in the built environment [14].

The main purpose of biophilic architecture is to provide and sustain the need for positive experiences with natural systems and environments in the built environment, which are crucial for human performance and well-being in modern life. Structures where biophilic components such as natural lighting and natural ventilation are effectively used bring users closer to nature. On the other hand, they maximize the heating, lighting, and ventilation performance of the structures and facilitate the formation of environmentally friendly buildings [14].

In architecture, biophilic design elements such as gardens, inner courtyards, living walls, rooftop gardens, vertical forests, etc., can be evaluated as design components that can be applied in various forms and methods. The intensive use of vegetative materials can also be considered in architectural biophilic design.

From past to present, the connection between humans and nature in architectural scope has diminished over the last 250 years due to the widespread urbanization of contemporary cities. [15].

The increasing world population and rapid urbanization lead to the time spent in external environments transitioning to human-made environments. Therefore, there is a need for natural elements in all environments where people live. The transformation of society, daily life, and industry has led architects to focus on incorporating elements referring to nature into the built environment after the negative impact of the detachment from nature on human physiology and psychology.

2.5 BIOPHILIC DESIGN PRINCIPLES

Unfortunately, modern society presents numerous barriers to experiencing nature positively. There is a growing detachment from nature often notable as a resource or leisure facility. This disconnect is evident in various sectors like Industrial, health, agriculture, education, urban design, and architecture these lead to significant obstacles to designing the built environment, where humans now spend most of their time. Despite the need for contact with nature remains essential for health but achieving it in a built environment is challenging. Modern design often treats nature as an obstacle or unnecessary, leading to insufficient access to natural elements like light, clean air, vegetation, and natural views and elements [14].

In one of the studies conducted by Kellert and Calabrese [103], Biophilic design has five basic principles that represent the main circumstances for correctly applying biophilic design. They include:

- a. Biophilic design emphasizes the sustain interaction with nature.
- b. Biophilic design emphasizes how humans have evolved to adjust to the natural environment, leading to long-term improvements in people's health, physical condition, and general well-being.
- c. Biophilic design enhances the feeling of connection to settings and places.
- d. Biophilic design develops positive relationships between humans and nature, expanding the sense of accountability for both the natural and human populations.
- e. Biophilic design promotes supporting architectural solutions.

Kellert and Calabrese[14]. Biophilic design approaches were categorized into three categories, and 24 experiences were based on nature's experiences to guide designers in using biophilic design examples for effective implementation. These categories are divided into experiencing nature directly, indirectly experiencing nature, and experiencing space and place, as indicated in Table 2.1. each of these three categories, when separated, highlights a fundamental element in which humans experience nature, thereby encompassing the actual application of biophilic design [14].

Table 2.1: Biophilic Design Qualities Developed By Kellert And Calabrese [103].

Direct experience of nature	Indirect experience in nature	Experience of space and place
Natural light	Images of Nature	View and Refuge
Air	Natural Materials	Complexity
Water	Natural colors	Whole part integration
Plants	Natural Light and Air Simulation	Transitional spaces
Animals	Forms and shapes	Mobility and wayfinding
Weather conditions	Inspiring nature	Cultural and ecological affiliation
Landscape	Richness of information	
Fire	Geometrics	
	Biomimicry	

2.5.1 Direct Experience of Nature

This means that individuals are in direct contact with environmental features like plants, Water, animals, etc., which already exist in the built environment, experiencing nature through its elements [14].

Natural Light: Experiencing natural light is essential for human health, In addition to facilitating movement, it contributes to individuals' comfort and satisfaction. Natural daylight is defined as a significant and preferred attribute by individuals for maintaining a healthy life in a home. Experiencing natural light increases morale, well-being, health, and productivity [14].

The combination of natural light and shadows creates aesthetically appealing shapes. As seen in Figure 2.4, natural light can be applied to the interior space using glass walls, suspended ceilings, reflective colors, and textures. The dynamic experience of natural light can be achieved through the contrast of light and dark spaces or the change in daylight over time [14].



Figure 2.4: Allergo Office. Warsaw Poland 2017 [17].

Air: Natural air is an essential and vital design element for human comfort and productivity [18]. The quality, movement, flow, scent, and stimulation of senses such as touch and sight, including visual attractiveness, of indoor air significantly impact spaces, and users express that natural air enhances comfort, concentration, and productivity in work environments [14].

The healthiest and most natural ventilation method in a building where biophilic design is applied is to incorporate fresh air into the indoor space through windows that can be opened to the outdoors [18]. Airflow, temperature, and humidity can be experienced by enhanced natural ventilation in built environments. As seen in Figure 2.5, windows are a simple way to access natural and clean air.



Figure 2.5: An Opening Window In The Meeting Room For Ventilation [19].

Water: Experiencing water in the built environment reduces stress and increases satisfaction, essential for human life. The experience of water also improves human health and performance [14]. Generally, humans react strongly to water, one of their most basic needs. People typically prefer spaces with water elements [3]. The attractiveness of water is mainly associated with multiple sensory perceptions such as sight, sound, touch, taste, and movement. The desire for contact with water can be satisfied through various design strategies. As seen in Figure 2.6, in the built environment, water generally provides satisfaction when perceived as clean and experienced different senses [14].



Figure 2.6: Changi Airport Singapore [20].

Plants: are the most important and valuable approach to achieving the direct experience of nature , including plants and greenery increases human health, productivity, and well-being [4] Abundant and ecologically integrated plant coverage is necessary in buildings and landscapes [14].



Figure 2.7: Weekend House In Downtown São Paulo / SPBR Arquette's [21].

Animals: Throughout human history, the life of animals has been an inseparable part of human experience [14]. Animals are utilized both as companions and friends and for protection against external factors [18].

Studies emphasize that people living with pets tend to be more confident, physically fit, more inclined to exercise, and experience less loneliness [22]. Pets reduce human stress and anxiety. Interactions with animal life should include as much species diversity as possible and prioritize native species over non-native ones [14]. As seen in Figure 2.8, various design strategies, such as feeding stations, green roofs, gardens, aquariums, aviaries, etc., can be utilized for positive interaction with animal life, along with the creative use of modern technologies such as webcams, videos [14].



Figure 2.8: Living Room With Fish Tank [23].

Weather: A key component of human relationships with nature throughout history has been awareness of and response to the weather. For human life and survival, this awareness and response are critical. People feel fulfilled and are encouraged when they perceive the weather and interact with the air in the built environment. This can happen when you are directly exposed to the outside environment or simulate the weather by adjusting humidity, temperature, barometric pressure, and airflow. Design elements such as gardens, windows, awnings, terraces, balconies, and awnings can account for changing weather conditions [14].

Natural Landscape and Ecosystem: Including plants, water, soil, rocks, and geological formations in the built environment, Humans prefer landscapes with expansive environments with trees, water elements, and forests. Design strategies such as artificial wetlands, forests, meadows, and green roofs can create self-sustaining ecosystems in the built environment. These ecosystems can be supported by the strength the relationships with natural systems, viewpoints, observation, and active participation [14].

Fire: Control over fire is one of humanity's most outstanding achievements. Fire enables the utilization of energy and facilitates the transformation of objects beyond the capabilities of animals. Generally used for heating and cooking purposes, fire presents a complex and challenging design option in the built environment. Control of fire within structures has been passed down as an experience that provides a pleasant feature of colors, temperatures, and movement [18].

Experiencing fire provides both comfort and anxiety. Additionally, it draws people's attention and facilitates meditation, contributing to socialization by bringing people together [14].

Indoors, fire is primarily used in fireplaces, providing visual warmth rather than as a heating source. As seen in Figure 2.9, fireplaces and hearths add a central mark to the space with the fire's appearance, sound, and aroma, creating a unique ambiance.



Figure 2.9: Chimney Usage In The Interior Design Of The Living Room [26].

2.5.2 Indirect Experience of Nature

This refers to the representation or imagery of nature, exposure to transformations, or specific patterns and processes. It involves contact with nature through the representation to natural patterns. Indirect experience of nature includes elements such as pictures, wooden furniture, natural materials, patterns influenced by shapes and forms found in nature, and environmental cues like the passage of time and a sense of aging [14]. Features included in the biophilic design as part of the indirect experience of nature are as follows:

Images of nature: The visual representation of nature can be achieved through various means such as photographs, paintings, sculptures, videos, etc. The impact of a single image of nature is generally minimal. The effectiveness of nature representation lies in its repetition, thematic consistency, and abundance [14].

Natural materials: when used, strengthen the sense of belonging to the environment and become more valuable as they age and bear the marks of time. Natural materials such as

wood, stone, wool, cotton, leather, etc., are found in various products, furniture, fabrics, and designs; natural materials are utilized in unique forms such as flooring, wall and window treatments, doors, furniture, and lighting fixtures [14] [22].

Natural Colors: When employing color in biophilic design, it is advisable to lean towards subdued earth tones reminiscent of soil, rock, and vegetation. While incorporating bright colors, caution is necessary, with a focus on accentuating natural elements like flowers, sunsets, rainbows, and specific flora and fauna. Avoiding highly artificial, contrasting, and overly vibrant color combinations is best [14].

Natural Light and Air Simulation: Progress in building technologies and construction techniques has enabled the illumination of indoor areas and control over airflow. Artificial lighting can imitate the spectral and dynamic characteristics of natural light. Likewise, natural ventilation features, including airflow, temperature, and humidity, can be evaluated through processed air [14].

Forms and Shapes: Integrating natural forms and shapes enhances the appeal of structures. These forms, inspired by elements from the natural world, are commonly incorporated into the exteriors and interiors of buildings. They can turn a static environment into a dynamic one that mirrors the environmental traits of a living system [14].

Inspiring Nature: The essence of nature can be taken through imaginative, even representations that do not exist precisely in nature can derive design principles and attributes from the natural world [14].



Figure 2.10: The Guggenheim Museum In Bilbao, Spain. [27].

The richness of information: The enormous variety and variation of elements found in the natural world are so profound that they have been compared to the most information-dense environment people would ever encounter. When faced with surroundings rich in information and diversity, whether natural or artificial, that presents a multitude of options and opportunities, people tend to respond well to them, so long as the complexity is communicated in an easy-to-understand way[14] in Figure 2.11 The Eden Project consists of several biome domes that simulate different natural environments, such as rainforests and Mediterranean landscapes. Visitors can explore diverse plant species and learn about various ecosystems, providing an immersive experience rich in information and biodiversity.



Figure 2.11: Eden Project In Cornwall, England [28].

Natural Geometries: Among the mathematically characteristic features standard in nature are hierarchical scales and curved, self-repeating variable patterns organized hierarchically. Fractals and hierarchical scales such as the golden ratio [14]. We can see in Figure 2.12 an example of a skyscraper that features a series of curved, self-repeating patterns that resemble fractals. The design also incorporates hierarchical scales, with the building tapering towards the top, reminiscent of the golden ratio. These natural geometries not only improve the aesthetic aspect of the structure but also contribute to its structural stability and efficiency.



Figure 2.12: The Distinctive Skyscraper In The City Of London [29].

Biomimicry: Defined as the emulation of forms, shapes, and functions observed in nature, finds extensive application in the built environment. Numerous instances in nature, such as the robustness of spider webs, the thermoregulation mechanisms of termite mounds, and the insulation provided by specific animal fur, inspire technological innovations [14].

Biophilia is a Greek term that combines "Bio," meaning life, with "Philia," meaning love. It signifies a deep affection or attachment towards one's existence. Please refer to the source [105] for further information. Biomimicry, derived from Greek roots, combines "bio," meaning life, and "mimicry," meaning inspiration, resulting in the concept of nature-inspired design [105].

Inspiration from nature has been classified into the third levels: Living Object "Organism" Behaviour, and Ecosystem. The individual organism's characteristics may inspire the Design, or it may be inspired by the behavior of the living object, or the design may be inspired by the entire ecosystem of the living being and its surroundings [105].

2.5.3 Experiencing Space and Place

Experiencing space and place expresses the characteristic spatial features of the natural environment that enhance human health and well-being. Spatial features such as landscape, shelter, integration of parts, mobility, and wayfinding are integral to experiencing space and

place[14]. Features included in experiencing space and place as part of biophilic design are as follows:

View and Refuge: Humans have evolved in response to the complementary benefits of hope and shelter. View or prospect is the long views in the environment that allow individuals to perceive opportunities and threats. Refugees provide security and safe areas. These two complementary conditions are functional and satisfying in the built environment. View and refuge can be achieved by creating visual connections between landscapes, interior spaces, and secure, sheltered environments [14].



Figure 2.13: View And Refugee Example [30].

Complexity: Humans often admire the complexity of natural and artificial environments, which symbolize prosperous settlements regarding preferences and opportunities [14]. However, excessive complexity usually leads to confusion [4]. Environments containing complex features are also the most satisfying [14].

Part-Whole Integration: Environments where different parts are integrated attract human interest. The sense created by the emergence of a whole can be achieved through clearly distinguishable boundaries and the sequential connection of spaces. A functional or thematic central focal point can develop satisfying integration in space [14].

Transitional Spaces: Clear and recognizable connections between generally open and noticeable areas facilitated by transitions are necessary to navigate an environment successfully. There are areas where corridors, thresholds, doors, and passages connect internal and external spaces (awnings, terraces, courtyards, columns, vaults, etc.) [14] [15].

Mobility and Wayfinding: Generally, individuals' comfort depend on their ability to move freely among various complex spaces. Clearly understood entrance and exit paths and points are crucial for fostering mobility and a sense of security. Otherwise, they can lead to confusion [14].

Cultural and Ecological Affiliation: People's affinity for familiar settlements reflects a regional tendency that can be developed through cultural and ecological means. Ecological connections to a place can give good emotions to an area [14]. Environmental and cultural attachments motivate people to preserve and sustain nature, cultural attachment is a universal human need that ensures the preservation of architectural heritage, primarily through valued and unique local forms [15].

2.6 THE NEGATIVE SIDE OF THE BIOPHILIC DESIGN ELEMENTS

Despite much research that proves the benefits of biophilic design and its effect positively on humans physically, psychology, and sociology, other studies recognize some adverse effects that reflect on humans and energy and different aspects; in the table below, the strengths and weaknesses will be examined.

Table 2.2: Strengths And Weaknesses Of Involving BDEs In Design With Examples.

The BDEs	Strengthens & Opportunities	Weakness & threatens	Examples
Daylight	Shadows and the transitions of natural light through openings between indoors and outdoors increase productivity and provide an aesthetic aspect to the place [31].	The distribution of light and glare could affect visual performance. High temperature in the space leads to overheating[31] [16].	 Institut du Monde Arabe, Paris (France) [106].
Air	Enhance the quality of air circulation and ventilation and expand thermal comfort [14].	Potential increase in pollution Overhumidity and moisture could cause Mold issues [32].	 Mountain Restaurant & Bar, Zunyi (China) [106].

Table 2.3: Strengths And Weaknesses Of Involving BDEs In Design With Examples "Table Continued".

Water	Create a good feeling and diversify your sensory experience, which improves mood. Moreover, it provides places with cool weather [14].	-The quality of acoustics could be influenced by the high voices of water in the place. -The biophobic possibility could affect people emotionally negatively [14] [5].	 Apple's Piazza Liberty Store, Milan (Italy) [106].
Plants	-Expanding of green space. -Stress reduction -Enhancing productivity Reduce air pollution. Reduce the building energy consumption [34].	- structural problems, over-humidity, and regular maintenance needs for artificial elements [34].	 Musée du Quai Branly, Paris (France), [106].
Animals	Create a suitable ecosystem and form a landscape for soil, stones, and geological features [14].	Biophobic problems of contacting some animals, Regular follow-up is required for dead animals. [5]	 Mellor Primary School, Stockport (UK) [106].
Landscape	Improve the quality and connectivity of landscapes in an environmentally sustainable way. Maximize the efficiency of the natural environment while minimizing the need for management [14].	Artificial and superficial adornments, solitary and unusual arrangements of plants - Insufficient involvement and engagement - Insufficient housing and inadequate proximity and elevation for optimal landscape observation [5].	 Chichu Art Museum, Naoshima island (Japan) [106].

Table 2.4: Strengths And Weaknesses Of Involving BDEs In Design With Examples "Table Continued".

Wheather	Biophilic design gives importance to all types of openings like windows, terraces, courtyards, etc. These raise awareness to designers to experience the weather through open roofs or domes, to access the sunlight, airflow, humidity, temperature, etc [2].	Climate change and extreme weather adversely affect individuals' well-being and comfort [34].	Sun Rain Rooms, London (UK) [106].
Time and seasonal changes	Provide various senses and quality of mood improvement [14].	Buildings or spaces can be at risk of damage over time - Differences in people's preferences and feelings regarding seasons and time.	Bosco Verticale, Milan (Italy) [106].
Forms and shapes	Replicate the shapes and patterns found in living organisms (known as biomorphic design) while creating architectural structures, systems, components, and interior spaces. Biomorphic elements encompass various botanical and animal themes, such as shells, spirals, eggs, ovals, tubular forms, arches, vaults, and domes.[35].	Excessive and repetitive employment of forms and shapes can lead to visual monotony and increased cognitive sharpness [14].	Metropol Parasol, Seville (Spain) [106].
Patterns and Geometry	Enhance the creativity of architects and designers. Moreover, they are utilizing cultural patterns.	Duplication and repeated patterns are not preferable to visual performance.	Agri Chapel, Nagasaki (Japan)[106].

Table 2.5: Strengths And Weaknesses Of Involving BDEs In Design With Examples "Table Continued".

Connection to place	Forge links across several dimensions such as culture, history, geography, and ecology. -Produce a feeling of belonging and fulfill desires for familiar locations (place attachment) -Facilitate a feeling of inclusion and enhance self-awareness by incorporating individual components into a unified entity (establishing a connection with nature). - Promote relaxation and enhance psychological well-being and feelings of comfort and security.	Failure to comprehend cultural and contextual nuances might result in the dissemination of improper information or the perpetration of abuse. A feeling of bereavement may be triggered when the designs undergo a negative alteration or are destroyed.	 Ningbo Historic Museum, Ningbo (China) [106].
Mechanism	Optimize building performance by improving indoor comfort and reducing energy usage. Enhance the efficacy of constructing resources and the capacity for self-adjustment and self-regulation. Explore innovative architectural forms and structural designs, such as large-span structures, thin-shell structures, or membrane structures.	Human attempts to replicate nature are bound to result in errors, which can disrupt the delicate balance of an ecosystem and pose additional threats to the whole ecological system. - Emphasize replication of outward appearance and outline, while disregarding efficiency and practicality in the framework and building process. Enhance the durability of the building.	 Beijing National Aquatics Center, Beijing (China) [106].

Table 2.6: Strengths And Weaknesses Of Involving BDEs In Design With Examples "Table Continued".

Images	A strong connection with Nature, especially in closed hospitals or offices - positively impacts behavior and causes less anxiety, fear, and stress [14].	It depends on a person's preference for images and may cause negative reflection of undesired elements. [14].	 Erasmus MC Hospital, Rotterdam (Netherlands) [106].
Materials, colors, and textures.	Promoting Sustainability by using friendly materials and replacing concrete and steel Organic shapes and colors affect people's moods and behavior [35].	The efficacy of the green color scheme in actual surroundings is unknown. Excessive brightness or high-contrast colors can create pressure effects, while certain colors, such as rotting brown, might evoke unpleasant connotations. Disagreements arise about raw, handcrafted, and artificially produced natural materials [35] [106].	 Panyaden School, Chiang Mai (Thailand) [106].
Mystery	Provide beautiful attractions and Increase the Opportunities to use land. Scrapes and greenery[35]	-Risk of physical injury -Psychological negative issues and discomfort -Maintenance cost. [35].	 Los Angeles County Museum of Art, Los Angeles (US) [106].
Prospect and refuge	Creation of happiness and safety via open views Attractive scenes for users Reduce the stress [15].	This element depends on the Availability of views and the surrounding environment. And the difficulty of differentiating between prospect and refuge [15]	 Arango Marbrisa House, Acapulco (Mexico) [106].

Table 2.7: Strengths And Weaknesses Of Involving BDEs In Design With Examples "Table Continued".

Complexity	Rich details and information could be of interest to people Also, it encourages architectural innovation to build different and attractive facades [35].	Repeated geometries or fractal shapes. And lack of information could be reached despite the complexity [15].	 King's Cross Station, London (UK) [106].
Connection of space	Taking into consideration the movement of users and mobility through corridors. Foyers etc [35].	A single function for the transition spaces could be monotonous and insufficient [15].	 Frey House II, Palm Springs (US) [106].

2.7 BIOPHILIC DESIGN FOR SUSTAINABLE ARCHITECTURE

In architecture, sustainability has been extremely studied and incorporated since the 1990s. Different sustainable strategies have been explored in response to various environmental challenges, such as climate change, resource savings, and sick building syndrome [36].

The strategies for integrating sustainable ideas with the field of architecture include drawing design inspiration from nature and natural systems, as well as renewable, recyclable, and natural materials. The "plurality" of these design methods and challenges has been praised, as they defy easy categorizations within sustainable architecture to create a healthy built environment for the present and future generations [36].

"Sustainability" is still a complex term in modern times, and many conflicts are involved in reaching the main goals. In addition, many sustainability challenges have been recognized, and how the stakeholders respond to these accepted challenges to improve and update specific sustainability design objectives and design goals to align the design of buildings with these goals.

Scachfers [36] suggests discovering how to apply the concept of sustainability with architects, engineers, or even clients. Moreover, comprehends the idea of sustainability in architecture by bridging many difficulties and design purposes or goals.

Biophilic design (Eco-friendly) provides various strategies to support sustainability in architecture. Many researchers [36] [14] [39] emphasize the strong relationship between biophilic design and sustainability and how integrating them in a design could lead to comprehensive achievement for design, built environment, landscape, interior spaces, etc....

Sustainable design aims to reduce the use of non-renewable energy sources, save energy, and decrease pollution. Through these ideas, good architecture should help combine the goals of sustainability with a design approach to meet the needs of today's requirements without impacting natural resources and prioritizing environmental features [39].

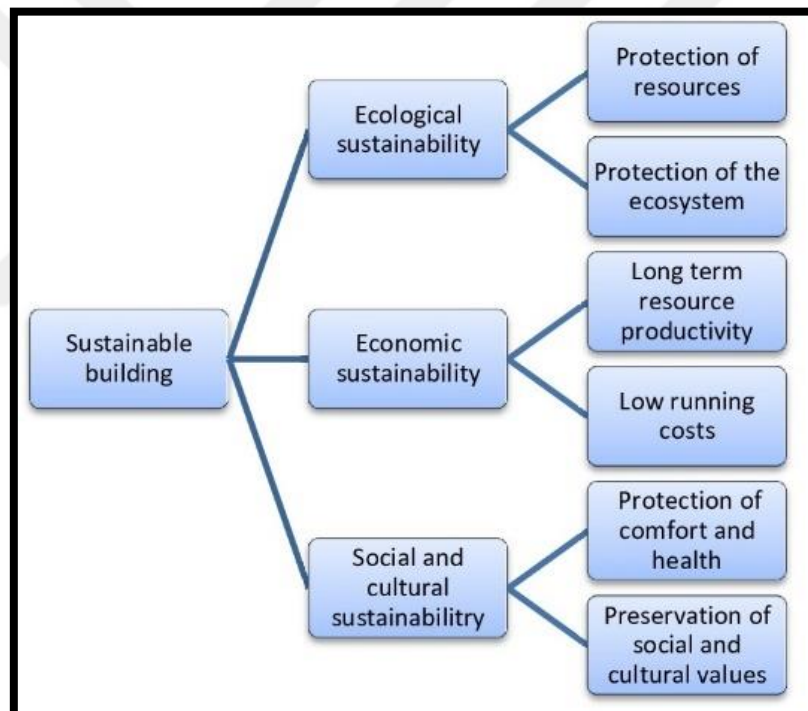


Figure 2.14: The Researcher Kohler Classified Three Dimensions Of Sustainable Building [84].

Ecological sustainability includes actions done to protect ecosystems and environmental resources. This covers crucial tactics like favouring environmentally friendly processes, using natural resources sparingly, and gravitating toward renewable energy sources [40] [36].

Economic sustainability includes the usage of cost. Choosing reasonably priced, reusable, and extremely durable building components and materials during construction improves

resource efficiency over the long run. Simultaneously, economic sustainability is attained by reducing building consumption costs due to elements like energy efficiency, simplicity of operation, and maintenance [40].

Social and cultural sustainability focuses on Maintaining people's comfort and well-being; structures and initiatives must be planned to improve people's quality of life, satisfy societal demands, and preserve cultural heritage. As a result, buildings serve society's social and cultural demands for a very long time [36].

Green design is a strategy meant to reduce negative environmental and health effects. This method emphasizes human health concerns and environmental sustainability at every stage of building design, construction, usage, and recycling. The phrase "green design" refers to architectural architecture that is done with consideration for the environment [40].

At the end of the 20th century, design with natural techniques emerged. While several approaches considered sustainability concerning resources and nature, biophilic design is the only approach that specifically highlights the sustainability of human-nature interaction in built environments. By designating it as the "**missing link** of sustainable design," [40].

2.7.1 The Sustainable Development Goals (17 SDG)

In 2015, the countries in the UN created the 2030 Agenda for Sustainable Development. According to the World Health Organization (WHO), the Sustainable Development Goals (SDGs) seek to positively change our world, end poverty, ensure all people have good health, and protect the planet for future generations.

The 17 Goals outlined in the study consist of 169 targets. Mossin and her colleagues [108] have offered additional insights into the challenges that architecture must address. Studies by [106] identify the different challenges encountered in the field of sustainable architecture. Summarize the benefits of biophilic design from the literature review and correlate them with challenges in sustainable construction. [108].

Since 2015, numerous academics have done studies demonstrating the necessary involvement of architecture in achieving these 17 goals. These studies have also highlighted the primary responsibilities of architects, designers, and engineers in this progress [44].

Rosemary Chidimma, O. Francis Ogochukwu, and S.-A. Chinwe, in their investigations, demonstrates numerous functions [108].

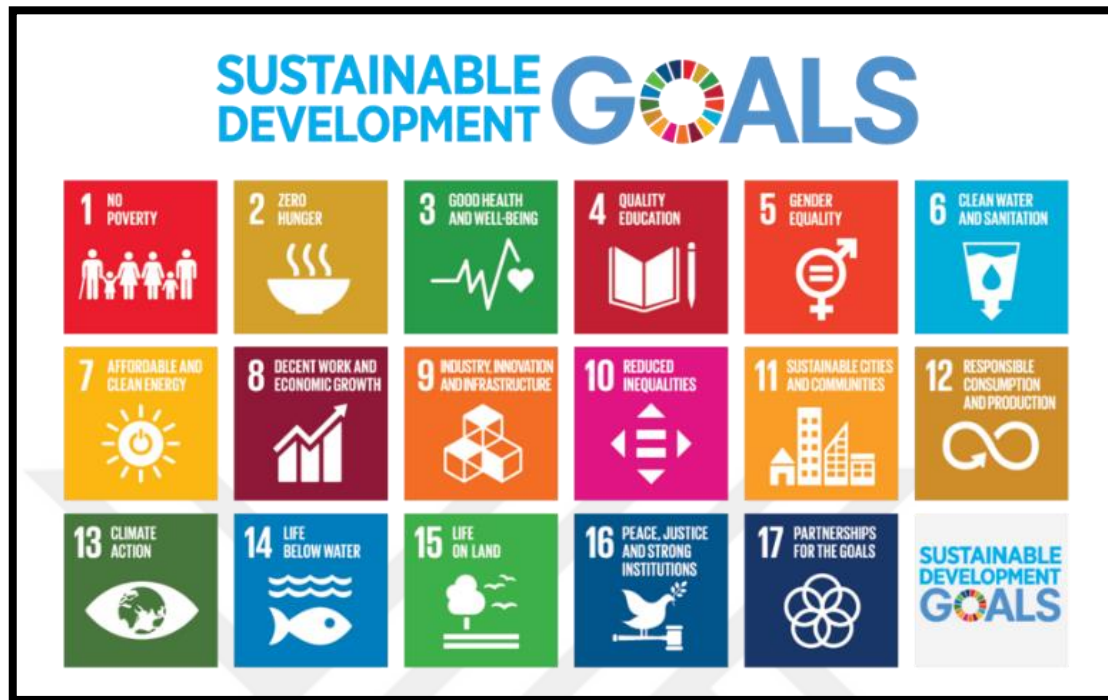


Figure 2.15: The 17 SDGs Of The UN [43].

Weijie Zhong, Torsten Schroder, and Juliette Bekkering [106] analyzed the advantages of biophilic design based on existing research and correlated them with specific obstacles in sustainable building. The following table illustrates the correlation between sustainability and biophilic design based on past research and the most essential features of biophilic design [108].

Table 2.8: Benefits Of Biophilic Design To Address The Challenges Of Sustainability.

The17SGDs	The general roles of architect	Challenges in sustainable architecture	Benefits of biophilic design	BDE
No Poverty	Building and planning with cheap, safe, and healthy materials Making people save on electricity and other utilities [44]	Affordability	-Reduce energy and materials cost	Air Plants Water Textures
Zero hunger	Building landscape design should be in areas where food production is available and accessible [44].	Food security	Enhance food production	Plants

Table 2.9: Benefits Of Biophilic Design To Address The Challenges Of Sustainability "Table Continued".

Good health and well-being	Architects should consider ventilation and natural light. Acoustics. Settlements should depend on reducing the risk of any accidents or spreading diseases and not using harmful materials [44].	Avoid the spreading of diseases. Non-toxic environment Healthy and comfy indoor spaces.	Reduce stress. -increase treatment and healing rates. Improve physical activities and enhance emotions. Provide thermal comfort.	Water Air Plants Colors Mystery Prospect and refuge. Daylight Images Landscape Materials and textures
Quality education	Building the capacity and raising awareness for sustainable buildings by providing training or sharing these in the design itself [44].	Training, and capacity building education on sustainable performance in the learning environment.	Increase attention and creative performances. And memories restoration. , raise the awareness.	Air Daylight Plants Landscape/
Gender equality	Public spaces and facilities should be safe for all genders also, playgrounds, and public grounds should offer women and girls access to their activities [44].	Difficulties of diversity and gender considerations [106].	Give examples of taking gender into account.	Plants Landscape
Clean water& sanitation	-consider the rainwater collection method in designing. -separate the wastewater from the rainwater. - building and sewage systems should not mix the clean water with any potential bacteria. -The built environment should consider climate change related to water, such as floods [44].	Collecting the rainwater Issues related to climate change[106].	Water management.	Water Weather

Table 2.10: Benefits Of Biophilic Design To Address The Challenges Of Sustainability ”Table Continued”.

Affordable and clean energy	By designing an optimal building layout, energy consumption could be reduced. Analyzing the climate conditions, and geographical and cultural situations. The use of daylight and natural ventilation Choosing the dimensions of walls and openings can minimize the undesired weather conditions without energy consumption [44].	Energy usage for cooling, heating, and lighting Geographic climate and cultural circumstances[106].	Decrease energy consumption,	Air Daylight Plants Weather
Good work and economic growth	Safe, affordable routes to the workspace to be designed healthy and productive for the users, -Ensure the safety of the employees and reduce the number of raw materials. [44]	Good Health and productivity of employees in all kinds of workplaces[106].	Increase retail potential. Enhance employee productivity, mood, and well-being [45].	Mechanisms Air Daylight Plants Landscape Images
industry, Innovation, and Infrastructure	The building industry should focus on the lifecycle perspective to avoid waste production [44].	Develop the digital infrastructure. -promote the building standards regarding energy consumption and health[106].	Provide examples of using virtual reality in design [45].	Plants Time Forms and shapes

Table 2.11: Benefits Of Biophilic Design To Address The Challenges Of Sustainability ”Table Continued”.

Reduced inequalities	Architects should be responsible for designing accessible spaces according to functions, like lifts, ramps, stairs, and all relevant wayfinding. According to the height of the buildings [44].	Landscape qualities. Including all communities and groups of people to access public infrastructure[106].	Provide public green and blue spaces [45].	Water Plants Landscape
Sustainable cities and communities	The provision of affordable and healthy environments helps to reduce pollution and improve accessibility between cities. Architects can make cities safer, resilient, and sustainable through design [44].	Safety and resilience of cities Affordability, mobility, and accessibility[106].	Increase Liveability. Decrease violence.	Water Air Daylight Plants Landscape Weather Connection to place
Responsible consumption and production	A good design should consider the reduction of waste production by ensuring durability and using material that can be recycled [44].	Using local materials. Durability of the building [106].	Increase Lifespan. Strengthen using native plant varieties.	Plants Materials, textures, and colors Connection to place
Climate action	Integration of renewable energy production and reducing transportation of materials can reduce Co2 impact. -Architects can control energy consumption by applying specific designs for lighting and air conditioning in indoor environments. - changing	Climatic comfort without energy consumption. Resilient to any dangerous changing conditions like rainfall and floods [106].	Reduce energy consumption through the effects of climate. Reduce the urban heat effect Enhance wind protection. Consider the local topography and climate.	Water Air Daylight Plants Landscape Weather Connection to place

Table 2.12: Benefits Of Biophilic Design To Address The Challenges Of Sustainability ”Table Continued”.

Life on land	Architects could support the ecosystem by including spaces for plants, insects, and animals. -using renewable materials to avoid deforestation [44].	Support, restoration of ecosystem and biodiversity	Enhance the diversity of living organisms and promote the process of renewal and regrowth. Create and maintain habitats for animals, particularly in urban environments.	Connection to place Plants Animals
Peace, and strong institutions	Through buildings, settlements, and public spaces, architects should add values regarding safety and ensure avoiding abuse, exploitation, or any form of organized crime. [44]	Safety, and affordability of public spaces.	Provide places with shadows and suitable shelter.	Prospect and refuge Plants
Partnerships for the goals	Architects can be involved in sharing sustainable solutions and engaging with related peers for implementation[44].	Coordination between the stakeholders continues to build networks among the professionals[106].	Enable the professionals to organize the work together.	All biophilic design elements
Life below water	Reducing the approach of transportation of building materials for a long distance.	Low cost of water management. Decrease the pollution of lands near the sea and oceans.	Reduce water pollution.	Water, Plants And animals

It is observed that architecture does not have a direct relationship with all SDGs. It is essential to acknowledge that the architectural field does not equally contribute to all the Sustainable Development Goals (SDGs). As reference [46] stated, The World Green Building Council identified 9 of the 17 Sustainable Development Goals (SDGs) that have the most significant potential to be accomplished through design. The table illustrates how biophilic design is pertinent to many Sustainable Development Goals (SDGs), including workplace well-being. The primary factors closely associated are optimal health and well-being and climate change [106].

3. OFFICE DESIGN AND ITS ERGONOMIC CRITERIA

3.1 DEFINITION OF OFFICE BUILDINGS AND DESIGN OF OFFICE BUILDINGS

The word 'office' root is back to the Latin word 'opus', which means work and innovation. Also, the origin of the word 'office' includes the word 'circle,' so the word 'office' exhibits a complex structure by establishing a relationship between thought and circle. It is obvious that this relationship could be infinite because in medieval Latin, 'official' means to perform a religious ritual, deriving its meaning from the infinity of its name and the infinity of thought [53] [54].

According to Arch. U. Cassan, an office is a place where various tasks such as management, clerical work, accounting, and design are carried out by employees who work at desks suitable for their specific tasks [53].

Globalization, technological advancements, and changes in design principles have influenced office designs. Therefore, recently, office designs that deviate from mere functionality and appeal solely to aesthetics have been replaced by designs that maximize employee motivation, comfort, and productivity, positively affecting their psychological well-being [54].

3.2 HISTORICAL DEVELOPMENT OF OFFICE BUILDINGS

The office concept first emerged during the Industrial Revolution, from 1760 to 1840. During this period, new factories emerged, and as industrialization extended, administrative support was required [57].

It was at this period of technical advancement that office spaces first developed. Usually, these areas were found in warehouses or industries. The highly functional workplaces of today are nothing like the ones from the past. Their primary purpose during design was paperwork and record-keeping. Naturally, this modification led to the creation of white-collar workers [57].

During the second half of the 19th century, factories occupied European capitals, employing hundreds of individuals. These businesses had offices where employees could spend the

entire day performing calculations, maintaining records, and interacting with hundreds if not thousands, of other employees [57].

The initial office structures were built during this period. These structures resembled contemporary workplaces in that they featured expansive, open spaces and corridors of workstations. The rapid advancement of technologies, including telephones and typewriters, engendered a necessity for enhanced privacy within the workplace. Presently, workplaces serve as social spaces where individuals contribute to the development of the commercial world [57].

As previously stated, the emergence of offices has transformed workplaces into social environments. This change in their operation necessitated the creation of separate offices for managers and executives, who frequently dealt with highly sensitive information [57].

The phase of partitions and screens during this period signified the introduction of measures to ensure privacy for other employees. At the same time, with the rapid increase in requiring highly qualified professionals in white-collar occupations, the role of being an office employee has become more esteemed and financially rewarding than in the past.

The post-World War II period witnessed substantial transformations in everyday existence. However, one of the most conspicuous changes occurred in architecture and workplaces [57].

The stage of the modernist style in the mid-20th century transformed office design, favoring more efficient and practical spaces. As well as the notion of open offices came into being. This innovative style was characterized by spacious areas with multiple rows of desks and small partitions separating personnel. The design concept was centered around the objective of enhancing efficiency through the promotion of collaboration and cooperation among employees inside companies [57].

Meanwhile, modern workplaces include new technological advancements, including photocopiers, intercom systems, and many electronic devices. Employees may execute duties more efficiently and with less effort. These technological breakthroughs enabled workplaces to improve their productivity and efficiency [57].

However, certain employees also expressed criticism towards open offices. The primary factors contributing to certain employees' dissatisfaction with working in a spacious space alongside several colleagues were excessive noise, frequent distractions, and a lack of personal privacy. Consequently, several organizations began experimenting with novel

hybrid designs that integrated open spaces with private areas, such as meeting rooms or individual offices [57].

In the 21st century, the COVID-19 pandemic has emerged, leading to a huge increase in remote work.

The work culture has changed, affecting both physical designs and conceptual frameworks. Workplaces have seen changes due to shifts in work patterns, technological improvements, and priorities [57].

Numerous organizations continued experimenting with hybrid designs, including an open office area and separate offices assigned explicitly to senior staff. However, the prevailing design typically included many departments in their designated areas. This architecture resembled open workplaces as several departments operated in a communal, unenclosed area [57].

Furthermore, the widespread technologies have led to the emergence of remote work and the economy. However, a noteworthy occurrence has made remote work more prevalent and widely accepted than ever before. In little than a year, the emergence of COVID-19 significantly altered the understanding of work. This occurrence prompted many white-collar employees to transition to remote work and operate from their residences. Moreover, during the pandemic, there was a significant increase in the number of independent workers, indicating a profound transformation in the future of work culture [57].

Indeed, open workplaces did not cease to exist with the COVID-19 pandemic. A significant number of employees still expressed a preference for working in a physical office but with certain modifications. Previously, all employees desired privacy. However, following the epidemic, individuals sought similar comfort in their jobs as they experienced in their homes. Companies responded to these desires by adopting new regulations, creating hybrid schedules, and providing employees with private places, such as work pods and phone booths, to escape the distracting office atmosphere.

While it is challenging to predict the exact nature of future workplaces, it appears that there will be an increase in both privacy and personalization [57].

3.3 SPATIAL ARRANGEMENT OF OFFICE BUILDINGS

According to Toprak et al. [55], Office buildings consist of three central units: working, circulation, and service areas.

Working areas: These are the primary units of an office. The employees who implement their work can be individuals or a group of staff. The working areas are also divided into personal and executive offices, including rooms for managers, spaces like restrooms, and dressing areas. Also, working areas can have seminar rooms, training, or meeting rooms. [55].

Social areas: refer to integrated spaces that incorporate working and circulation areas designed to enhance staff productivity, introduce vibrant elements to the work environment, and mitigate apathy toward the external world [55]. The level of integration has notably risen, particularly during the 2000s, and specific social spaces have been specifically developed to cater to the requirements of employees. Social places that cater to requirements encompass facilities such as dining halls and cafeterias [55]; staff perceive leaving the workplace as a waste of time, so social areas are provided with facilities such as restaurants, shopping areas, open leisure areas, and publicly accessible libraries. These areas are also used by visiting clients and guests [55].

Support areas: refer to designated places specifically created to enhance the quality of work life and optimize the office's operational efficiency. The designated assistance zones encompass the following regions:

The information desk area is designed to enhance the accessibility of the building for exterior visitors.

Security measures are implemented to provide safety and protection.

Document registration for responsibilities relating to documents.

Office supplies and equipment for copying, stationery, faxing, and filing.

Emergency medical facility for urgent healthcare requirements.

Examples of areas designed to accommodate the demands of working moms, such as baby care rooms and nurseries, might be mentioned [55].

Technical spaces: The technical areas in the facility include server rooms for managing the automation system, kitchens, storage rooms for fixtures and tools, archives for old documents, floor service areas, machine and boiler rooms, water tank and hydrophore room, electrical panel room, and generator room [55].

Circulation areas are categorized into vertical and horizontal circulation zones. Vertical circulation spaces encompass many elements, such as floors, fire stairs, escalators, elevators,

and service elevators. The size and quantity of these elements are determined based on specific requirements. Horizontal circulation zones encompass floor lobbies and corridors connecting offices and floor lobbies, providing a shared space for employees and external visitors. Horizontal circulation areas function as both transit places and social venues for personnel [55].

Enhancing interpersonal interactions among staff is a crucial factor in designing circulation zones that serve as bridges between working areas in an office, illustrating that circulation areas serve as connectors between working areas. Enabling communication among staff members in different working areas demonstrates that circulation areas can be strategically planned to encompass social places like cafes and libraries [55].

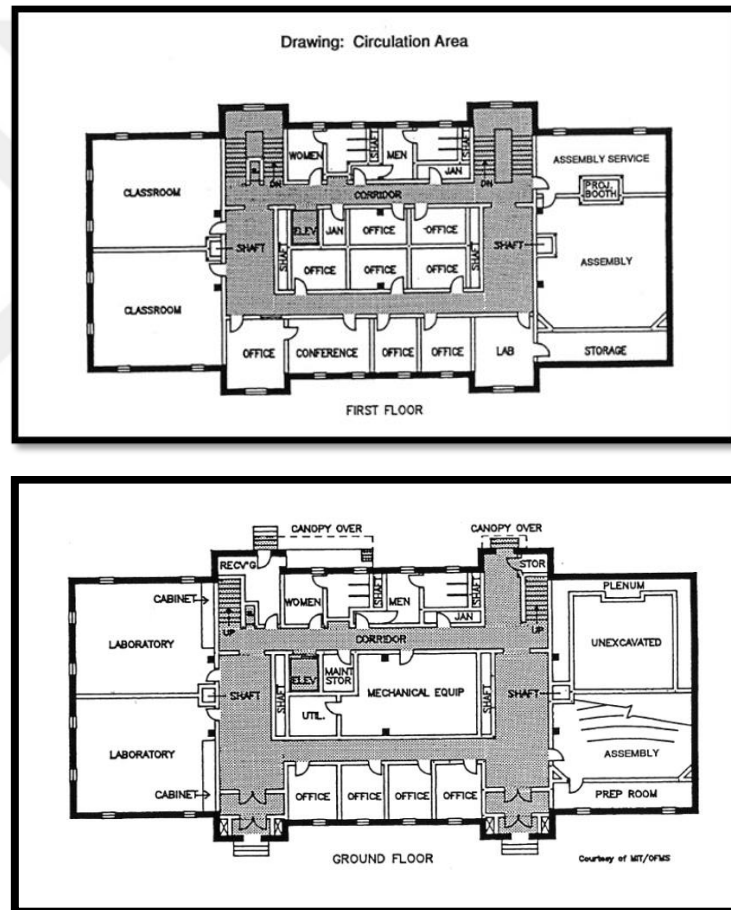


Figure 3.1: Example Of Circulation Area (Shaded Area) [61].

The physical arrangement of office buildings is directly connected to the circulation spaces. The configuration of circulation zones might change depending on whether the workplace has an open or closed office approach. Within an office setting, it is crucial to have well-

designed circulation zones that promote convenient access to different locations, seamless transitions between spaces, and efficient communication [55],

Design of service spaces: The layout of service areas on floors is crucial for the smooth functioning of office spaces and circulation areas, serving the needs of floor personnel and staff. Typically, service spaces are planned together with vertical circulation areas. If they are not planned together, they are incorporated into the layout of office spaces on different floors [55].

The plan (layout) of offices

Despite variations in floor plan layouts in office buildings, the fundamental principles remain the same. The width of a building is estimated based on optimal lighting for workspaces and the determination of single or multiple corridor systems. Placing service areas in central and sun-shielded areas to ensure that all offices on every floor have equal conditions, with full and unobstructed views and access to air and light, reflects the contemporary approach to open-plan layouts effectively [55].

Offices are divided into six groups based on plan variations.

- a. Open office.
- b. Free plan layout.
- c. Cellular office.
- d. Group plan office.
- e. Combination office.
- f. Mixed office [55][59].

Open office design refers to a layout that consists of larger spaces, often spanning a whole floor, except executive rooms and service facilities [55]. As depicted in Figure 3.2. the figure shows that open offices lack partitioning barriers. The user's text consists of the numbers [55][59]. Open offices utilize furniture, low panels, planters, and other decorative elements as barriers and sound regulators to accommodate numerous employees working simultaneously. The open office layout optimizes spatial utilization, enhances adaptability, and bolsters staff efficiency across all operational endeavors. The open office layout promotes individual communication and engagement by removing the division between management and staff. [55][59].

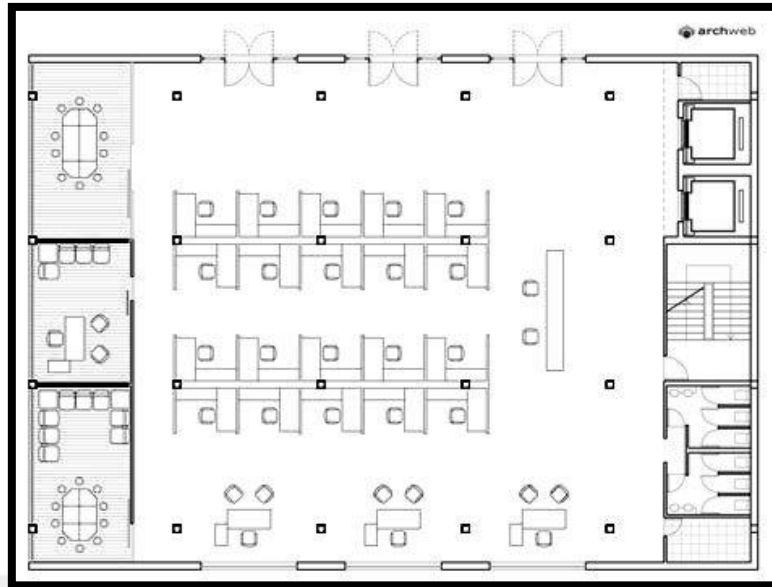


Figure 3.2: Open Office Layout Example.

Free plan layout refers to a design arrangement with no dividing walls or partitions, as depicted in Figures 3.3 and 3.4. The furnishings are organized inside their respective areas. This layout disregards status distinctions, with all employees operating under uniform conditions. The defining feature of the open plan concept is creating a spacious and unobstructed area devoid of partitions, resulting in a condensed arrangement [59]. The flexible open plan design implies the presence of dispersed yet systematically arranged work areas within an open workspace, as opposed to a linear layout. The design categorizes all activities conducted within the company primarily based on their purpose and arranges diverse workspaces to facilitate mutual access and interaction among these functions. It is possible to obtain flexibility in the plan, establish a centralized archive system, and minimize the number of interconnected documents using this approach.

The utilization of communication technology enables the establishment of a seamless workflow and the elimination of barriers between managers and employees while retaining a "control and supervision mechanism". It emphasizes the importance of workgroups [59].

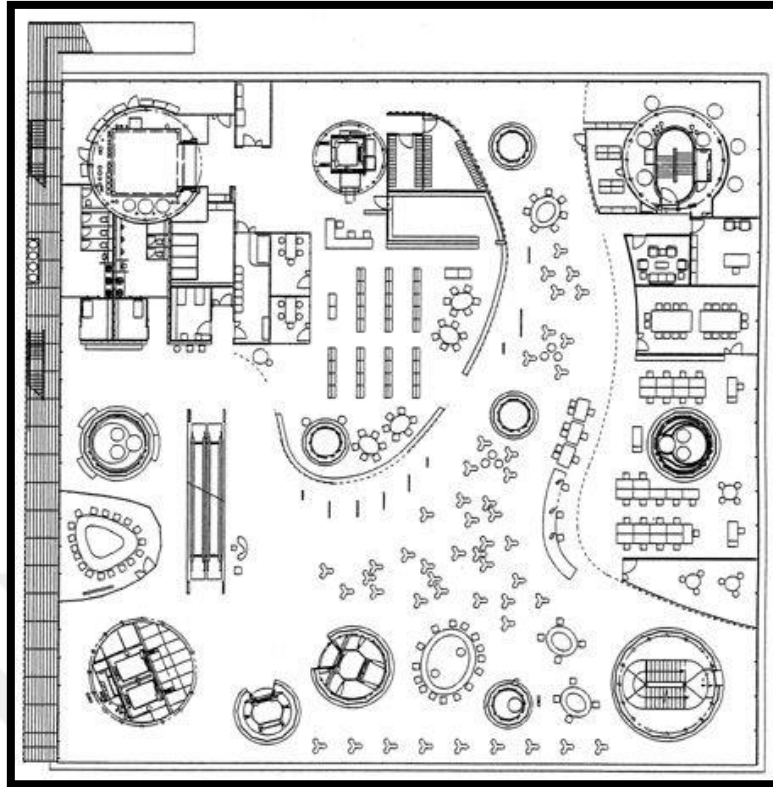


Figure 3.3: Free Plan Office Example [64].



Figure 3.4: Free Plan Office Example [65].

Cellular layout: Cellular offices, as seen in Figure 3.5 are units formed by dividing a space into multiple cellular compartments. Cellular offices symbolize the status of personnel. The design of cellular offices, with low human interaction, was initially inspired by the in-home office model that emerged during the Industrial Revolution. Cellular offices are commonly used in management-focused public buildings and are employed in private office buildings.

Cells consist of rooms of various sizes tailored to specific needs. In cell-type offices, which often benefit from natural lighting, the depth is less than 6 meters. The width of cells can vary depending on the office staff and their positions. Employee privacy is crucial in cellular offices prioritizing quiet, calm, and individual work [59].

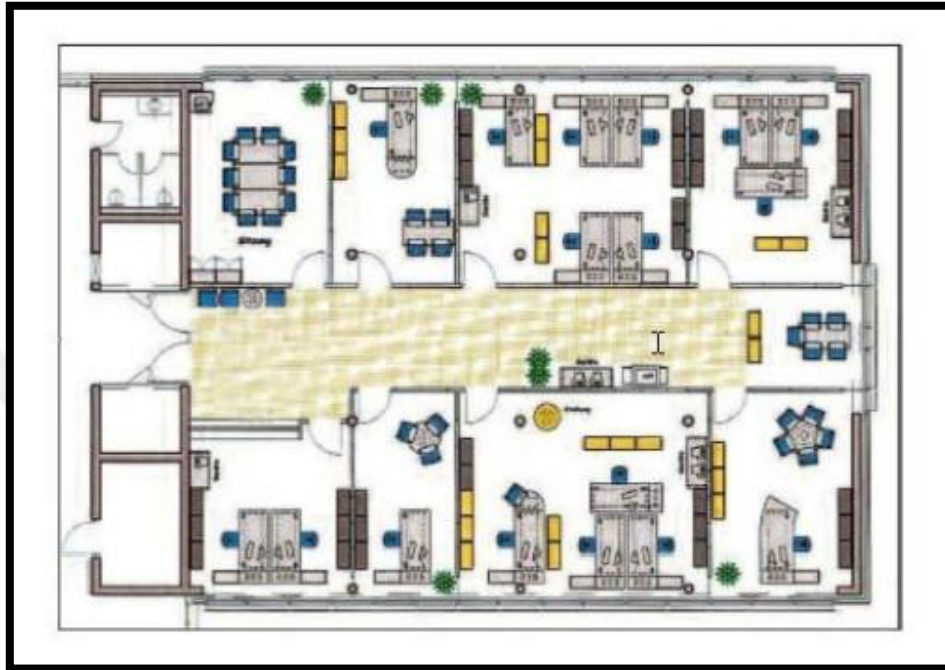


Figure 3.5: Cellular Design Plan Of Office Example [59] [63].

The group plan layout: As seen in Figure 3.6 is a configuration in which the individual workspaces typically found in single-person cellular offices are organized to support groups of either 5 or 10 individuals. This structure has been described by [55]. Group plan offices often use natural daylight, and the depth of the area can often extend up to 12-15 meters. The depth of the space is determined by considering the availability of daylight. In this design, the corridor is included in the workstation, allowing for direct linkages between offices through vertical circulation features.

This facilitates communication among staff working on similar activities [55]. Group plan offices have a limited impact on the internal spatial layout of office buildings. The attributes of group plan offices differ based on the nature of the work. Group plan offices can exist as independent entities or collaborate [59].

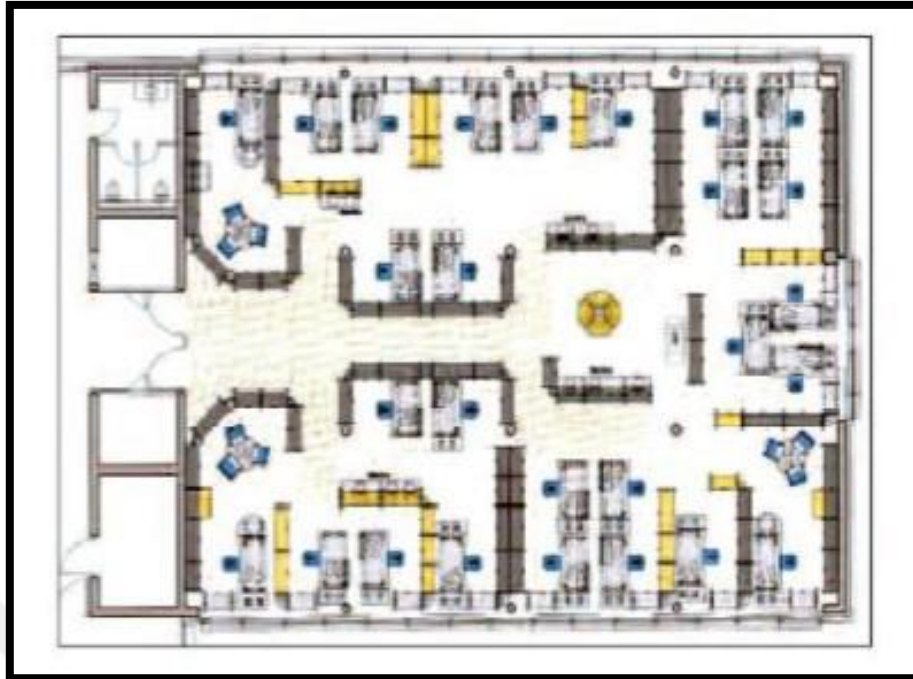


Figure 3.6: Group Plan Layout Example [59].

The combination plan layout: refers to a design that includes combination offices, which are areas that accommodate both individual and group work. The combination office concept originated in Northern Europe and consisted of separate enclosed quarters and shared spaces that facilitate mutual communication and group work among people [63] [59]. In centrally situated collaborative workspaces, tasks are typically carried out together using shared areas like conference rooms and vertical and horizontal circulation zones. Combination offices that are positioned next to walls are smaller in size compared to cellular offices. Consequently, these offices are utilized for solitary tasks [63] [59].

In workplaces that incorporate a combination of open and cellular office layouts, there is a noticeable differentiation in hierarchy or rank. According to Toprak et al., Figure 3.7 shows that the personnel of a unit who execute the same responsibilities work in an open office, but the unit's managers have their own separate enclosed office within the unit. [63] [59].

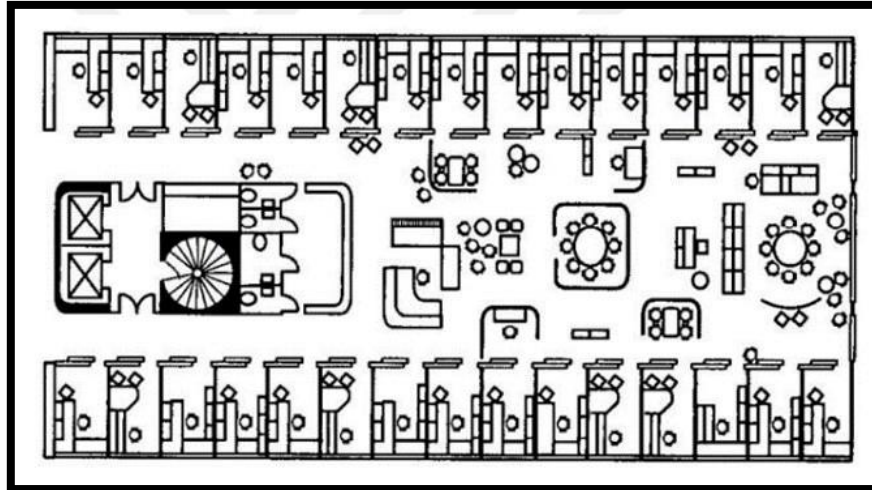


Figure 3.7: Example Of Combination Layout [63] [59].

The mixed layout plan: encompasses the characteristics of an open, group plan, free plan, and cellular office systems. Mixed offices effectively resolve the privacy concerns of open office layouts and the communication challenges encountered with cellular office layouts. Users can open or close interior dividers based on their preferences. Figure 3.8 demonstrates that mixed offices facilitate collaboration across diverse workgroups [59].

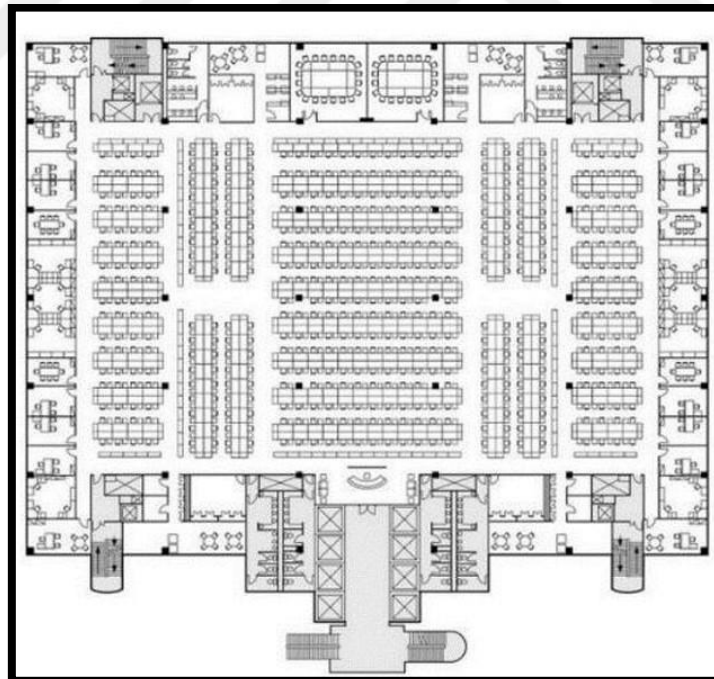


Figure 3.8: Mixed Plan Layout Office Example [63].

3.4 ERGONOMIC DESIGN OFFICES CRITERIA

Nowadays, and in recent living conditions, the growing number of workplaces requires office designs that follow ergonomic principles and promote the well-being of employees.

Offices without ergonomic design, which do not prioritize compatibility between the office environment and human needs, can result in the gradual onset of physical discomfort and exhaustion for employees, leading to long-term health difficulties. In such instances, the efficacy and output of employees in the professional setting are adversely impacted, leading to a decline in productivity. Hence, organizations seeking to enhance productivity should prioritize the ergonomic design approach. [60], Moreover, a comprehensive examination of the existing research reveals that implementing ergonomic practices in workplace settings benefits both productivity and comfort. To mitigate such issues, limiting or eradicating all variables contributing to stress in the work environment is imperative. When planning, it is important to consider parameters such as office ventilation and climate conditions, brightness level, sound and noise control, personal distances, work surfaces, and equipment dimensions. These considerations aim to enhance employee performance and address physical and psychological stress factors [58] [60].

The primary environmental elements in the workplace that significantly affect employees and require preventive measures can be enumerated as follows:

- a. Illuminate Systems.
- b. Acoustic management.
- c. Climate control systems.
- d. Selection of the colors.
- e. Utilization of equipment [58].

Considering these variables, creating a workplace that adheres to ergonomic principles and meets necessary physical conditions can enhance productivity by reducing employee weariness and enabling more efficient work. Moreover, it can contribute to preserving both the physical and mental well-being of personnel [58] [60].

3.4.1 Illuminate Systems

Enhancing visual comfort qualities in workspaces is widely recognized to improve productivity and performance. Upon examination of studies conducted within this domain, it is evident that the brightness level impacts workers' visual comfort conditions. A study [76] [66] comparing two workplaces with brightness levels of 960 lx and 1500 lx revealed that the environments were evaluated differently. Furthermore, it was observed that luminance levels exceeding 1500 lx were linked to negative attitudes among the workers.

Simultaneously, a fall in brightness level was perceived with more intensity than an increase. Other studies have found that a brightness level of 800 lx at the work plane was considered favorable, and increasing the brightness level above 1300 lx did not significantly impact the overall visual comfort of the work environment [66].

A study conducted by Fleischer S. [76] on office workers revealed that persons working in environments with warm color schemes and low-intensity light sources reported a higher level of comfort. Simultaneously, individuals who encountered elevated levels of brightness reported feeling content with the environment. Upon assessing the findings, it was determined that workers' satisfaction is not influenced by the light color emitted by the light sources [66].

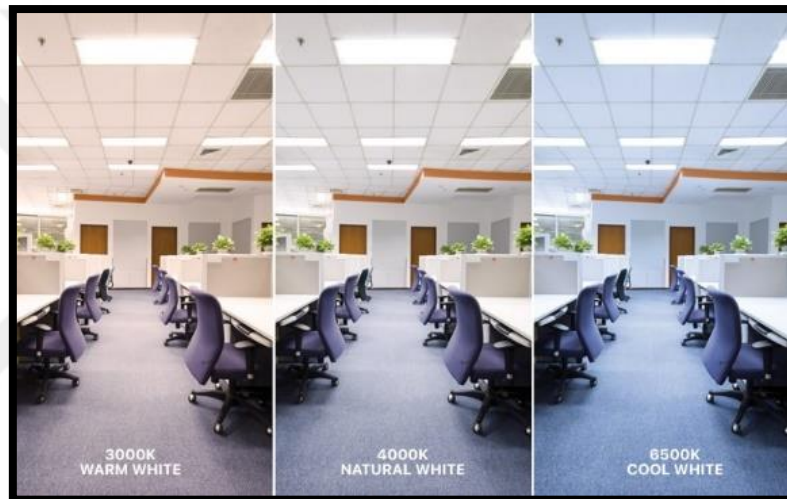


Figure 3.9: Example Of Difference In Lighting Levels In Office Design [75].

Research [66] has determined that inadequate lighting settings specifically designed for usage in workplaces might lead to headaches, mood disruptions, and eye tiredness among employees. Hence, it is essential to understand the impact of light on employee well-being in office lighting systems and to apply suggested measures to establish more productive work environments, which can favor user psychology. When designing lighting, it is crucial to consider essential aspects that determine the quantity and quality of lighting design, such as light color, angle of incidence, and quantity [66].



Figure 3.10: Some Effects Of Bad Lighting Design On Employees In The Office [74].

Offices can be lighted using natural, artificial, or a combination of both. For workplace spaces that have access to natural sunshine, it is important to design the desk layout to ensure everyone can achieve adequate levels of brightness. Artificial lighting is employed to augment natural lighting in situations when natural lighting is inadequate in office settings and work areas. Artificial lighting systems primarily employ fluorescent or mercury vapor bulbs that emit white light. Due to technological progress, a wide range of lighting systems and components have been explicitly created to illuminate office spaces. Engineers and designers should effectively incorporate the advancements and resources provided by technology to establish a functional work environment that ensures ergonomic conditions for employees. Optimal ergonomic conditions in workplaces can be attained by fulfilling the following criteria:

- a. Glare and reflections should be avoided.
- b. Vibrations caused by the light source should be measured.
- c. Undesired shadow formation should be prevented.
- d. The distances between the work surface and the lighting fixture should be well designed.
- e. Colors should be perceived appropriately [66].



Figure 3.11: Example Of Glare Issue In The Office Workplace [73].

Controlling the direct emission of light from the light source can prevent glare and reflections, which can also contribute to visual comfort [66].

Lighting systems should be designed uniformly in work environments, so the space between lighting fixtures should not exceed 1.5 times the distance from the desk to the fixture. Furthermore, the arrangement of the workstation lighting surfaces should be considered when determining the fixture's position. This will lessen unwelcome reflections and shadow creation [66].

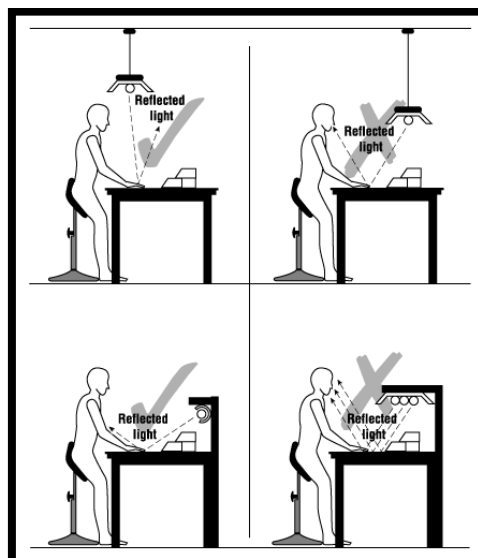


Figure 3.12: Showing Some Wrong And True Positions Of The Lighting Fixtures In The Office Desk [72].

3.4.2 Acoustic Management

Noise refers to a situation in which sounds exceed 40 dB. This feature holds great importance in mental and physical health, as it can have detrimental consequences and contribute to human stress. Therefore, ergonomic office design is a crucial aspect to consider. Prolonged exposure to elevated levels of noise in occupational settings can lead to impairments in attention, difficulties in concentration, and potentially even auditory impairment. This condition might create significant physical discomfort, reducing employees' performance and productivity and ultimately resulting in job loss. Furthermore, it can disrupt employees' concentration, resulting in absentmindedness [66].

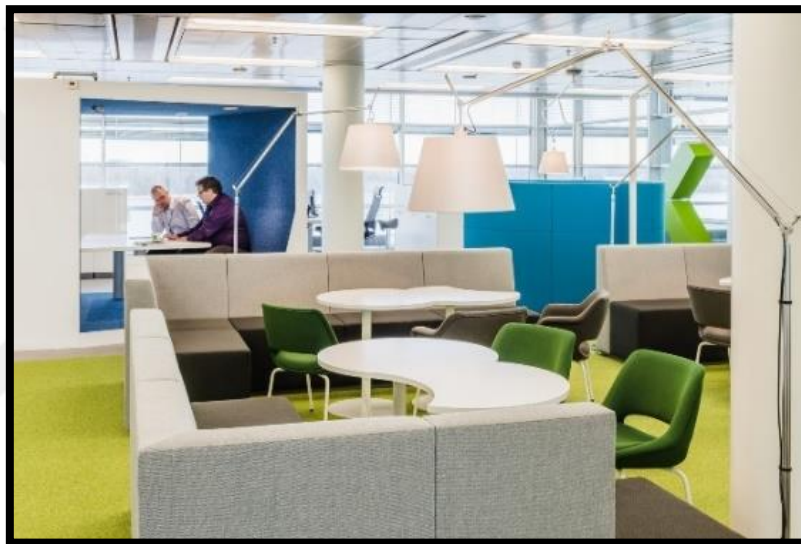


Figure 3.13: Example Of Managing Noise Pollution In An Office [67].

As technology has progressed and human health has become more significant, multiple solutions have been created to mitigate the adverse impacts of noise and sound in office environments. The systems consist of acoustic panels with sound-absorbing capabilities, partition elements, and textile materials, as shown in Figure 3.13 Furthermore, in order to minimize or eliminate noise in office settings, several steps can be taken as primary noise control measures. These include using rubber on table and chair legs, replacing a calling bell with a light warning system, utilizing soundproof materials like carpet and carpet tiles, employing textile-based curtains on windows, and installing lead or lead-dust soundproof wall panels [66].

3.4.3 Climate Control Systems

Optimal air quality, appropriate humidity, and controlled temperature levels inside indoor office environments are crucial for promoting employee well-being, efficiency, and effectiveness. The emission of toxic gases from electronic equipment within the office and the introduction of contaminants from the external environment negatively impact indoor air quality. To ensure the well-being of employees, it is imperative to maintain a constant flow of clean air indoors, which is essential for creating a pleasant and conducive working atmosphere. The lack of movable window systems in contemporary multi-story office buildings hinders the flow of natural air indoors. As a result, the interior environment cannot maintain a proper balance of humidity and temperature, which can negatively impact air quality and potentially cause a range of health and psychological problems for employees. Adequate air quality is crucial for limiting the spread of communicable diseases in enclosed, open, or partially open office environments where multiple employees occupy the same area. Ensuring thermoregulation within a specific range is crucial for human well-being and employees' comfort. Excessively high office temperatures cause less mobility and decreased effectiveness in both physical and cognitive duties. In contrast, excessively low temperatures lead to problems with concentration, reduced attentiveness, increased errors, and workplace incidents. Moreover, the interior humidity level also impacts the health of employees. Elevated humidity elevates the perceived temperature, rendering it challenging for employees to endure escalating temperatures, resulting in emotions of rage, restlessness, and stress. Low humidity can lead to inflammation in the respiratory tract and persistent coughing. To regulate humidity levels and mitigate their effects on employees' health, it is advisable to utilize various supplementary devices such as humidifiers, air conditioners, and fans. According to research, the optimal conditions for workplace spaces include temperature levels ranging from 21 to 23 degrees Celsius and humidity levels between 40 and 60 percent [66].

3.4.4 Selection Of the Colors

The various frequencies and quantities of light waves can create diverse colors, which in turn can affect human psychology and behavior through their low or high vibrational energies. Color is a significant factor in ergonomic office design as it has a direct impact on a person's mental state, leading to changes in both physical and psychological aspects,

ultimately affecting job performance in office environments. The impact of colors on human-computer-environment interaction is substantial since they affect humans' cognitive abilities, behavior, physical well-being, and psycho-social state. The element of color has been incorporated into different sectors, including architecture, graphic design, product design, machinery and device indications, and software ergonomics. Its impact on psychological consequences has made it a subject of multidisciplinary research for designers.

When considering the role of color in office ergonomics, the choice of colors in workstations is intended to promote concentration, attention, alertness, motivation, creativity, productivity, timeliness, hygiene, and comfort. This ultimately leads to increased efficiency in the workforce. In a study conducted by Manav B. et al. (2005), the relationship between lighting design and wall color in offices was examined. The study found that the color qualities of the light source affected how surface color was seen and influenced personal preferences. Research indicates that offices tend to favor light beige and light blue wall colors due to their association with feelings of comfort and spaciousness. [66].

A study conducted by Manny Downey, Kwallek N., et al. examined the impact of interior office color on the performance and productivity of employees. [69]. [70]

The table below shows some main colors and their effects on human psychology and interior office design.

Table 3.1: Table Showing Different Colors In Workplace Interior Design (by author).

The color	Features of Color and its impact on psychology
 Example of using blue color in office [69].	Blue has relaxing properties that provide a sense of peace and enhance productivity. It is well-suited for places requiring concentration and attention, such as creative studios [69] [70].

Table 3.2: Table Showing Different Colors In Workplace Interior Design (by author) "Table Continued".

 Example of using green color in office [69].	Green represents growth, harmony, and balance and has a refreshing and calming impact. It is particularly advantageous in diminishing stress and enhancing overall well-being. Integrating natural features and plants into the office design can amplify the beneficial effects of green. [69] [70].
 Example of using yellow color in office [69].	Yellow provides energy and makes the place more positive. It enhances the ability to think creatively and come up with new ideas. It can energize employees and foster a feeling of optimism and eagerness. Nonetheless, it is crucial to use yellow in moderation since an overabundance of vibrant hues can result in weariness or anger[69] [70].
 Example of using Red color in office [69].	Red is a color linked to passion and energy. It can elicit intense emotions and raise heart rate. Red is most effective in locations where physical exertion is necessary or instills urgency [69] [70].
 Example of using purple color in office [69].	Purple: A distinctive color that elevates any workstation, purple is symbolic of elegance, creativity, and spirituality. It can stimulate creative and imaginative thought. Use purple accessories or accents to inspire creativity and impart an air of luxury[69] [70].

Table 3.3: Table Showing Different Colors In Workplace Interior Design (by author) "Table Continued".

 White Example of using white color in office [69].	White Known for its simplicity and purity, white is a color that works well in a variety of settings and produces a minimalist workstation. It improves clarity and fosters an air of spaciousness and openness. White can be utilized as the main color or mixed with other colors to create a clean, contemporary style [69] [70].
 Gray Example of using gray color in office [69].	Gray is a classic, neutral hue with steadiness and harmony. It serves as a backdrop for more colorful elements in office decor and is frequently used as a base color. Gray can foster a composed and businesslike environment that helps people concentrate on their work without being sidetracked. [69] [70].
 Pink Example of using pink color in office [69].	Pink is frequently linked to femininity and sensitivity. It is a color that can bring a sense of warmth and playfulness to a workstation. It can establish a loving and pleasant atmosphere, making it well-suited for collaboration spaces or places designated for leisure. To prevent an overpowering impact, it is advisable to use pink in moderation. [69] [70].

3.4.5 Utilization of Equipment

Over the past six decades, there has been a significant transformation in working conditions as more and more workers have transitioned to sedentary employment. In developed nations, 75% of office workers perform their duties seated. This alteration has resulted in specific predicaments. Many people spend a large portion of their day sitting down and have significant physical issues due to using unsuitable furniture. Designing and selecting suitable seating equipment for work contexts necessitates medical and physical data about sitting. When analyzing the act of sitting from a physics perspective, particularly from other sciences

like ergonomics, it is seen that for an object to stay stable, it needs to be supported by a surface area. According to this principle, the mass will tip over if the weight vector strays from the vertical line that runs through the center of gravity to the ground. Human posture also conforms to this principle. During this phase, when the body's weight is carried by the feet, a portion of the load is sustained, while most of the weight is concentrated at the hips. Hence, office furniture and seating arrangements should be created explicitly for tasks performed while sitting to avoid the back and abdominal muscles malfunctioning.

Optimal measurements may differ due to variations in individuals' distinct physical attributes. Therefore, choosing furniture that can be adjusted and adapted is paramount. Incorporating adjustable seating mechanisms, which allow for customization of factors like seat height, armrest position, and backrest angle, is crucial in optimizing workplace designs and assuring optimal values. Furthermore, the inclination towards portable and revolving furniture fosters a sense of balance and unity between the worker and the workplace. This is because the employee possesses both a designated workstation and an additional area for activities and storage that is separate from the workspace.

Another important aspect to consider in work environments is the relationship between the seating unit and the work surface. The measurements related to this relationship have been determined within ergonomic standards and are illustrated in Figure 3.14

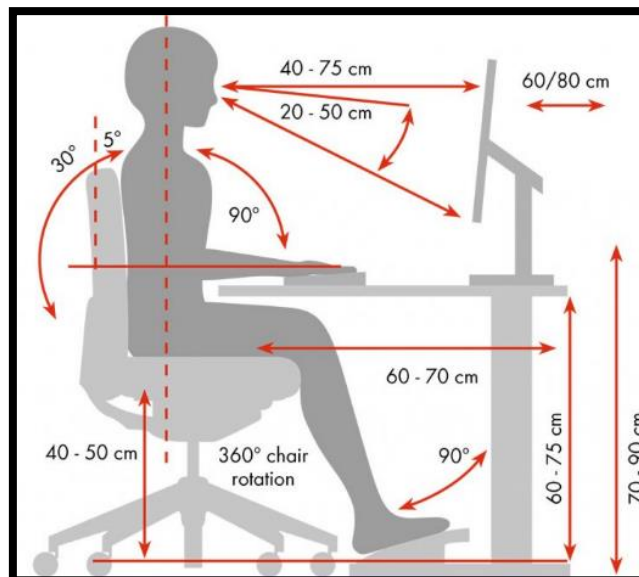


Figure 3.14: Minimum Standards Of Dimensions For Desk Setting Position [67].

3.5 PROBLEMS AND HEALTH ISSUES ENCOUNTERED IN OFFICES

According to a study by Akpınar et al. [47], employees who work in indoor environments may suffer from a lot of disorders, allergic diseases, psychological disorders, heart disease, diabetes, physical injuries, sick-building syndrome, visual weakness, tiredness, numbness, and functional impairments caused by physical environments [49].

According to the World Health Organization (WHO), health refers to a comprehensive state of physical, mental, and social well-being rather than only the absence of sickness or weakness. Therefore, a healthy office can be described as a work environment that, at the very least, does not negatively impact employees' well-being and, ideally, actively promotes it. Identifies specific symptoms associated with sick building syndrome [49].

Furthermore, research on this syndrome has been categorized into four headings:

- a. Air systems and air quality indoors
- b. Research on allergic disorders.
- c. Studies on chemical hazards.
- d. Studies of psychosocial factors from sick building syndrome [47].

The following factors by [49] were identified to measure the quality of the indoor environment, especially air quality in the workplace:

- a. Odours
- b. Temperature
- c. Air circulation
- d. Heat or glare from sunlight!
- e. Glare from ceiling light, especially on computer screens.
- f. Furniture crowding
- g. Noise and vibration levels
- h. The aesthetics of office design, such as color and style
- i. Natural light
- j. Location
- k. Workspace ergonomics, including the adjustability of computers, desk chairs, and all related furniture [49].

3.5.1 The Physiological Problems

Akpınar et al. [47] and Özdamar [50] claimed that potential physical sicknesses May occur with employees due to poor light, discomfort, and unsuitable temperature in an office environment. As well as remaining in the same position for a long period. Working on screens can cause problems in muscles and the skeleton; additionally, fatigue can prevent the body and immune system from continuing their functions properly.

According to Akpınar et al [47] and Özdamar [50], here are some diseases listed by assessing employees who are working in offices:

Musculoskeletal Diseases: The lack of information about using the body's muscles could affect joints, tendons, and ligaments. This leads to pain in organs such as the back, shoulders, knees, and neck, which affects bones and could even lead to a hernia, which affects the employee's performance [50]

In cases where people work in the same position, it also affects the blood flow, injuries, fatigue, and inflammation in muscles and bones, so employees should take breaks, breathing exercises, and stretching movements to avoid such problems [50].

Circulatory system diseases are unorganized physical movement and factors such as spending a long time in offices or in front of screens. This could lead to bad habits of nutrition as well, which increases stress, hypertension, Then arrhythmia, and even heart attacks [50].

Allergic Diseases: The ventilation system in offices and heating and cooling systems are also considered a significant factor in the thermal comfort of the bodies of people; individuals absorb smoking and chemicals while being in closed spaces, harming the Respiratory system and lungs, which leads to allergic diseases like burning in the eyes, swelling, color changes in the skin. As well as sneezing, runny nose, pain and inflammation of the throat, low blood pressure, shock, internal discomfort, swelling of the trachea, shortness of breath, and serious conditions. Therefore, maintenance and repair of mechanical systems in buildings should be routinely performed at regular intervals [50].

Physical fatigue: 80 % of the employees are suffering from long periods of work, the repetition of tasks, heavy workload, and hectic times, and this leads them to suffer from fatigue, which affects the performance of their work directly and indirectly and the functions of the organs of the body, especially in uncomfortable environment condition like extreme

weather, insufficient lighting, passive noise humidity levels. Those factors are beyond the scope of rescans of organs, which are workless and fatigued. [50] factors like different ages, diet habits, and genders surely also play an important role in body capacity, but in general, breaks and enhancing the surrounding environments could positively impact the body and increase the adaption to work and work efficiency [50].

3.5.2 The Psychological Disorders

In many cases, the heavy workload, pressure monotony, and economic issues affect not only the physical health of the employees but also their personal psychological and mental health; the high airflow, for example, can cause irritable behaviors while the low rate causes drowsiness and sleep cases among the employees, Noisy environments can increase the violence, insufficient lighting and ventilation can make people not feeling well which will be reflective to their behavior. Factors like Warm color, natural factors existence, and printed walls. Quality furniture could strengthen human relationships, improve people's communication levels, and positively influence their psychological health [50].

Stress: is considered the most critical psychological disorder in personnel from a health perspective. Stress causes anxiety, sadness, tension, and pressure in individuals.

Working environments should be designed to protect staff members' physical and emotional well-being to reduce stress in the workforce. This will protect employee health and raise production output. If this doesn't happen, employees will experience severe stress. Stress causes people to experience sadness, burnout, and loneliness. Conflicts arise in social and personal interactions as well. Stress plays a role in the development of psychological and physical disorders. The necessary actions must be completed in offices [50].

Burnout Syndrome: Staff who work under pressure and continue stress without any appreciation or with a high frequency of tasks and heavy workload could become burned out and lose control of their connection with colleagues, the environment, and their personal lives. This concept emerged in 190 in the United States, and social, personal, and service factors cause burnout. This leads the staff to have less motivation, a lack of energy, and a bad mood. The way to prevent burnout syndrome is to renew job organizations, management, and working conditions. The work environment should be free from an unsafe, complex, and intimidating atmosphere. [50].

Monotony: Employees who experience job and work life in the same place and in the same way daily feel bored and weary. In addition to decreasing job efficiency, productivity, quantity, and quality, monotony has psychological effects on staff members, such as sadness, reluctance, lethargy, exhaustion, and a loss of belonging. Diversity and career possibilities can be expanded to address this. Rotation is used to stop employees from doing the same things repeatedly. Poor performance, employee turnover, bogged down office work, and other related issues, such as decoration design and connection to nature, can be addressed using harmonious building designs and office furniture that resonate with the environment [50].

Absenteeism: According to Özdamar et al. Staff members who cannot participate in a work-related activity and are frequently absent without justification for their absence are considered absentees. In this instance, scheduled work hours are not given any thought. Depending on age, gender, and type of employment, absenteeism can happen after illness, accidents, holidays, and more. Examples of absenteeism include low staff morale and the "Monday blues" after holidays. When employees are absent from work, they do not produce as much after taking a break. Consequently, looking into, assessing, and dealing with the reasons behind employee absenteeism is imperative [50].

3.6 BIOPHILIC DESIGN BENEFITS IN OFFICE BUILDINGS

Today, people spend a lot of time indoors, and the priority in creating a space is the individuals who will use it. Living in spaces that do not meet the demands of users and fail to address their physical needs, safety, and privacy requirements can have many negative effects on people's psychology. In recent years, biophilic designs that utilize plants in various ways in outdoor spaces created by the interaction between workspace and external environments, as well as indoor workspaces, have been increasing. Companies consider biophilic design as a significant approach to increase employee productivity and motivation [80].

Biophilic design aims to enable employees to directly benefit from natural sunlight and air through accessible balconies, terraces, or gardens in the office, bringing them closer to greenery and nature. Green walls and plant coverings create a connection between nature and space. These applications increase productivity in employees, making their time in the

office more enjoyable. An analysis of the impact of biophilic design on employees found that elements such as sunlight and natural plants in the workspace increase productivity by 6%, creativity level by 15%, and happiness rate by 15%. In this aspect, biophilic design incorporates many design elements that involve experiencing nature visually, sensually, and aromatically [80]. In office designs, creating balanced spaces that unite nature and humans without isolating employees from the natural environment is of great importance [80].

Research on the impact of office spaces incorporating biophilic design principles, including direct and indirect exposure to nature and spatial experiences, has shown numerous advantages that improve quality of life, including productivity, performance, concentration, and positive emotions. Incorporating biophilic components in office architecture enhances staff productivity by 8% and well-being by 13%. Studies suggest that having direct exposure to nature might decrease stress levels and highlight the need to promote biophilic design in work environments [79] [14].

The inclusion of natural elements in work environments removes employees from the feeling of working in a closed environment that isolates them from natural life, noting strong positive relationships between natural daylight, fresh air, and the presence of natural vegetation in space. [89] state that the purpose of bringing more natural decor into windowless offices compared to offices with windows is to alleviate nature deficiency. In a study titled "The Relative Benefits of Green Versus Lean Office Space: Three Field Experiments" conducted in the UK, two different groups with varying levels of contact with nature were examined, and it was observed that employees with plants in their offices showed a 15% increase in productivity over three months [79] [14].

Kellert [79] expresses that when biophilic elements are included in work environments, mental fatigue, and stress decrease, and attention and concentration increase, positively affecting employee health by reducing absenteeism and increasing work efficiency. Kellert [79][14] states that enhanced natural lighting and ventilation maximize comfort and productivity for personnel by 6% to 16%. Improvements in natural lighting and ventilation increase work quality in personnel and reduce production errors [14].

In a study conducted in 1993 by Rachel and Stephen Kaplan [3] with 1200 office personnel, employees who had a view of nature from their windows experienced less dissatisfaction and were more willing to work compared to other employees. In a study conducted at the Herman Miller factory in Zeeland, Michigan, it was found that daytime employees with

access to daylight and nature views were more satisfied with the factory compared to nighttime employees [14] [80].

The biophilic design also significantly contributes to companies' economies [77]. According to J. H. Heerwagen et al. [1] and the NYC Economic Development Corporation in 2011. Implementing a biophilic design proves that employee absenteeism decreases by 10 %, saving the city of NYC \$470 million [77].

Heerwagen et al. [79] state that integrating sunlight effectively with office environments can save over \$2000 per employee annually. In an experiment conducted in the administrative office building of Oregon University, 30% of the offices in the building have a view of trees, 31% have a view of the street, and 39% are on the inner side of the building (office personnel were not hierarchically placed in offices).

Many personnel preferred a view of trees. Employees in offices with a tree view took an average of 57 hours of sick leave per year, while those without a view took an average of 68 hours per year. Employees in offices with a street view took more sick leave than those with a tree view and less than those without a view. Additionally, employees in offices with a tree view spent more time at their desks than others. Employees in offices with street views and without views spent their lunch breaks walking around various parts of the building. This demonstrates a significant connection between employees' access to natural views and job satisfaction, health, and productivity [79] [14].

4. CASE STUDIES OF BIOPHILIC DESIGN IN INTERNATIONAL OFFICE BUILDINGS

The purpose of the study is to analyze office buildings in terms of biophilic design through a literature review and qualitative research conducted within a theoretical framework, intending to propose solutions to the following questions:

- a. What are the contributions of direct and indirect contact with nature in the built environment to human health? How do the employees receive and be affected by the integration of the biophilic design elements into their workplace environment?
- b. Does the implementing biophilic design patterns create more environmentally sustainable office space?

These questions have been addressed within the scope of the thesis and answered through research. The findings have been evaluated, opinions and suggestions have been presented, and it is believed that they will assist future studies on biophilic features of corporate workplaces and office buildings in biophilic design this information will be discussed in the next section.

The literature review comprehensively covered national and international indexed journals, conferences, books, master's and doctoral theses, and related internet databases.

In this section, the selected office buildings will be evaluated according to the 15 biophilic design criteria prepared by Browning et al [16] [15] to answer the questions mentioned above. As a result of the literature review, it was observed that the biophilic design model prepared by Browning et al. [16] which is a simplification of the biophilic design model prepared by Kellert [40] can be easily applied in the design of office buildings. Therefore, the biophilic design model prepared by Browning et al. as shown in Table 4.1, will be considered when obtaining findings in the study.

It was observed that overseas examples were richer in biophilic aspects compared to examples from our country. Therefore, the study did not include a sample office building from our country. Two awarded international office buildings (Titan Integrity Campus and Amazon Spheres,) were selected for the field study.

In the evaluation table based on the classification by Browning et al. [15] [16], the presence of biophilic qualities was visualized with photographs of office spaces interacting with nature, and an attempt was made to determine the biophilic design qualities of the buildings. Thus, analyses were conducted on the quantity and variety of biophilic design elements applied in office buildings, which biophilic principles were commonly used, and which ones were neglected. The results were then tabulated for easier interpretation of the biophilic design principles present in the offices. After the tables were created for easier readability of the biophilic design principles present in the offices, the findings were evaluated, and all examples were comprehensively examined through a single table. It is possible to read from the table which principles are more commonly used in each office building and which ones are neglected.

The study done by Mengbi LI, Hing-Wah CHAU, [81] will be considered in the methodology of the study, it explains the three connected pillars, nature, place, and people as shown in Figure 4.1, and how it is related to the patterns of biophilic design given by Browning et al.[15] and the biophilic design principles presented by Kellert [40] it is combined into a matrix shown in Figure 4.2.

From a "nature" perspective, there are three domains: directness, natural features, and natural analogies. But when considering the "people" part, there are two specific areas of interest: the physical and psychological bonds with nature. The physical link with nature can be categorized into five subdomains: visual connections, somatosensory connections, auditory connections, olfactory connections, and gustatory connections. The psychological link with nature, also known as the intelligent interpretation of nature, can be categorized into four subdomains: prospect, refuge, mystery, and risk/peril.

From a spatial perspective, the biophilic design elements related to architecture and settlement can be divided into various subcategories. These include the region and its characteristics, the layout and organization of the settlement, such as the grid and axis, the design of streets, roads, lanes, and circulation, the integration of the site with the surrounding landscape, the choice of materials and construction techniques for the built form, the delineation of spatial boundaries, and the incorporation of symbolic meaning. The complex interconnections among the three pillars can be represented visually using a matrix in Figure 4.2 [81].

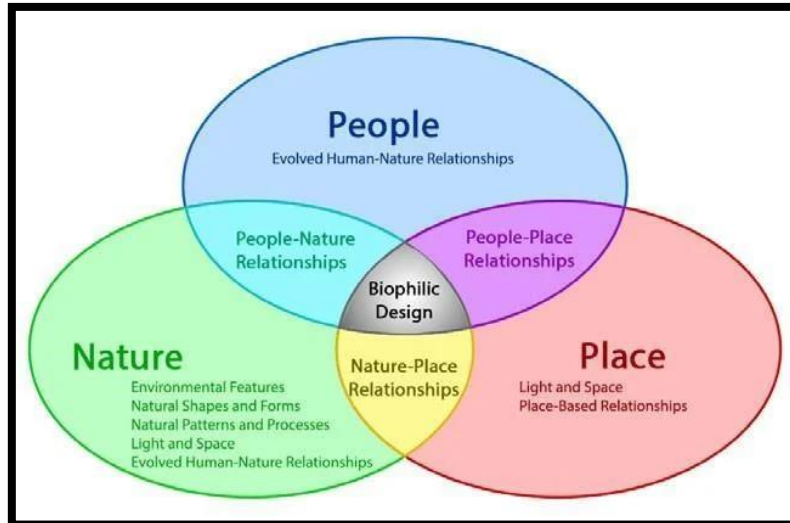


Figure 4.1: The Linking Between Nature, Place, And People And Biophilic Design [81].

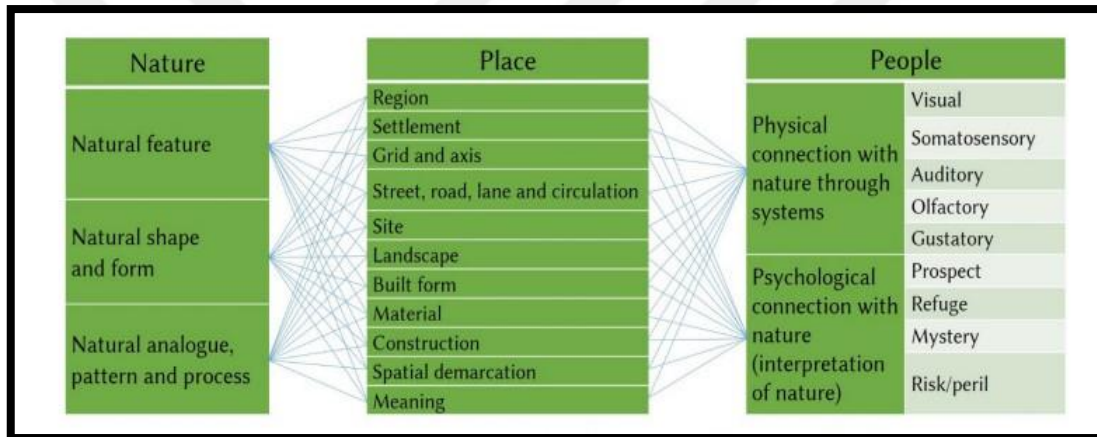


Figure 4.2: A Matrix For Evaluating Biophilic Design Patterns [81].

Table 4.1: The 15 Patterns Of Biophilic Design Extracted From Browning Et Al. [15].

Category	Design pattern	Definition
Nature in the space	Visual Connection with Nature	View of elements of nature, living systems, and natural processes [15] [83].
	Non-visual connection with Nature	Auditory, haptic, olfactory, or gustatory stimuli engender a deliberate and positive reference to nature, living systems, or natural processes [15] [83].
	Non-Rhythmic Sensory Stimuli	Stochastic and ephemeral connections with nature may be analyzed statistically but not precisely predicted [15] [83].
	Thermal and airflow Variability	Subtle changes in air temperature, relative humidity, airflow across the skin, and surface temperatures that mimic natural environments[15] [83].

Table 4.2: The 15 Patterns Of Biophilic Design Extracted From Browning Et Al [15] "Table Continued".

	Presence of Water	A condition that enhances the experience of a place through seeing, hearing, or touching the water[15] [83].
	Dynamic & Diffuse Light	It leverages varying intensities of light and shadow that change over time to create conditions that occur in nature [15] [83].
	Connection with Natural Systems	Awareness of natural processes, mainly seasonal and temporal changes characteristic of a healthy ecosystem [15] [83].
Natural Analogs	Biomorphic Forms & Patterns	Symbolic references to contoured, patterned, textured, or numerical arrangements that persist in nature [15] [83].
	Material Connection with Nature	Materials and elements from nature that, through minimal processing, reflect the local ecology or geology and create a distinct sense of place. [15] [83]
	Complexity & Order	Rich sensory information that adheres to a spatial hierarchy like those encountered in nature. [15] [83]
Nature of the space	Prospect	An unimpeded view over a distance for surveillance and planning. [15] [83]
	Refuge	A place of withdrawal from environmental conditions or the main flow of activity, where the individual is protected from behind and overhead. [15] [83].
	Mystery	More information is promised through partially obscured views or other sensory devices that entice the individual to travel deeper into the environment. [15] [83].
	Risk/Peril	An identifiable threat coupled with a reliable safeguard. [15] [83].
	Awe	Stimuli including other biophilic patterns that defy an existing frame of reference and lead to a change in perception [16] AWE patterns make people feel smaller, and humbler.

Office Buildings Examined Within the Scope of Biophilic Design

In this context, the designs of the structures seen in Table 4.1, which will be evaluated first, were discussed in general terms. Then, general information about the prominent features of the projects was provided to guide how interaction with nature could be implemented in different spaces. Subsequently, the office buildings were examined based on the biophilic design principles classified into fifteen items by Browning et al [15] and their characteristics were explained in the table with supporting images.

Table 4.3: Case Studies (Offices) Selected for Field Study.

Case study 1	Name	Titan Integrity campus
	Location	Bangalore, India
	Designed by	Sanjay Mohe, Swetha A, Joseph KT, Er. Mahesh.S
	Year	2017
Case study 2	Name	Amazon Spheres
	Location	Seattle, Washington, United States
	Designed by	NBBJ
	Year	2018

The Titan Integrity Campus was selected due to its exemplary integration of biophilic design in a tropical climate. The design team, led by renowned architects Sanjay Mohe and Swetha A, incorporated natural ventilation, extensive greenery, and water elements that create a harmonious interaction between the building and its natural surroundings. This campus serves as a prime example of how biophilic principles can be applied in an urban context to promote employee well-being and environmental sustainability.

The Amazon Spheres were chosen for their iconic and groundbreaking approach to workplace design. Designed by NBBJ, the Spheres incorporate a diverse range of plant species within a controlled indoor environment, providing employees with a direct connection to nature. This project highlights how biophilic design can be implemented in a densely populated urban area, offering a unique environment that fosters creativity, relaxation, and a sense of well-being.

4.1 CASE STUDY 1 TITAN INTEGRITY CAMPUS

The Titan Integrity Campus, situated in Bangalore, spans an area of 26,304 square meters. Designed by Mindspace Architects, the campus contains 3 floors with a built-up area totaling 36,232 square meters, the campus presents a harmonious blend of functionality and aesthetics. Completed in the year 2017, it stands as a testament to modern design principles and serves as a hub for innovation and productivity [85].

The design exhibits a unique connection with the location and the adjacent lake. The main concept was to maximize the utilization of all points towards the lakeside, which transforms any user into an observer of this calm environment.



Figure 4.3: Titan Integrity Campus [82].

A bio lake is planned on the site's eastern side, designed to complement the current lake and provide the illusion of being an extension of it. A proposal has been made to construct an office building and its associated facilities near this bio lake as shown in the site plan Figure 4.4. The structure is positioned so that its longer sides face the North and South directions, allowing for the entry of natural light without causing any glare. Porosity in planning and form enables the uninterrupted flow of air [82].



Figure 4.4: Site Plan Of Titan Integrity Campus [82].

The building consists of three floors, each equipped with a terrace garden. The design has interconnected green terraces, like rice fields, accessible by exterior staircases, creating an elevated sensation on each floor. Additionally, these terraces serve as a form of insulation for the office areas located below, resulting in a decrease in the need for heating and air conditioning. This aligns with the concept of creating a sustainable structure.

Green terraces allow work outside and encourage social contact among plants and animals. They also give pathways for individuals who want to take strolls. The proposed green walkway spans around 650 meters. Over time, vegetation would grow on the terraces surrounding the lake, gradually enveloping the structure, and transforming it into a non-constructed entity [82].



Figure 4.5: The Green Terraces Of Titan Integrity Campus [82].

In figure 4.6, a green wall garden on the western side protects the functional areas from the sun's intense rays in the west. Implementing a vegetated buffer zone between the green walls and functional areas efficiently reduces the impact of radiation.



Figure 4.6: The Green Wall In The Titan Campus [85].

The program is designed so that each department, such as Watches, Jewellery, Eyewear, Accessories, etc., has its distinct area while still being interconnected with other departments through spacious atriums. These atriums bring natural light, facilitate heated air escape, and accommodate elevators and staircases. The design of the workplace space ensures that natural light fills the entire area, reducing the need for artificial lighting.

Artificial lighting involves the utilization of light sensors and occupancy sensors for efficient planning.

The atrium ensures that there is never a sense of disconnection, fostering collaboration across different departments.

The campus features five atriums in figure 4.7 that vertically link all levels, including the basement, allowing natural light to permeate, and fostering a sense of unity, community, and cross-departmental contact [82].



Figure 4.7: The Five Atriums Of The Titan Integrity Campus [85].

Multifaceted glazed crystal, representing Titan's connection to jewelry, was crafted and positioned above the water along the middle axis. This was originally conceived as a part where designers from different departments would be gathered, showcasing Titan's expertise in design and innovation. However, as the design advanced, the second floor was transformed into a dedicated area for huddles and brainstorming sessions [82].



Figure 4.8: Photo From The Second-Floor Space In Titan Integrity Campus [82].

The temperature is consistently maintained at 27 degrees. Using ceiling fans to enhance air circulation and employ a two-stage evaporative air-cooling system that facilitates the

evaporation of water. The cooled and fresh air is then circulated inside the building. There is no air recirculation, resulting in the presence of 100% fresh air. Kumar explains that energy-efficient chillers are used to regulate humidity, and wind tunnels have been installed throughout the building to maintain a cool temperature [86].

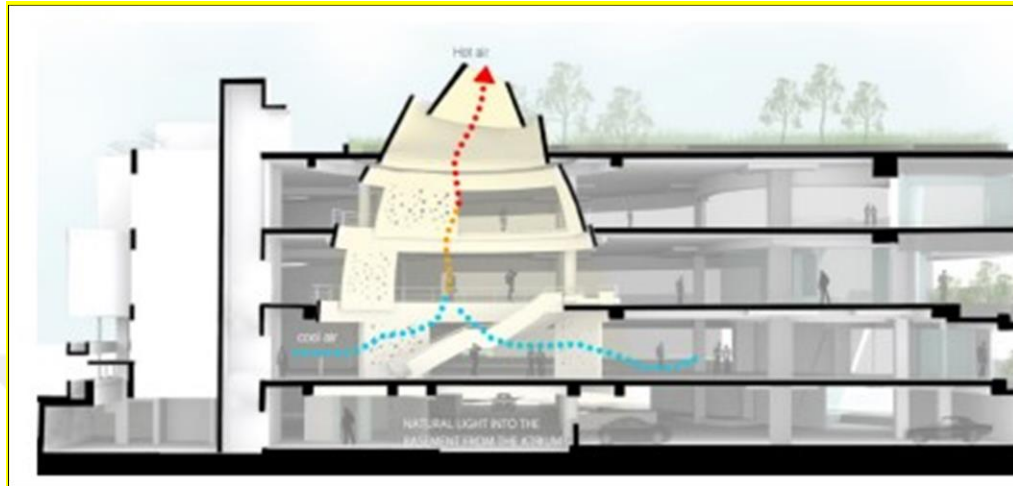


Figure 4.9: Section Plan Of The Atrium Of Titan Integrity Campus [82].

Considering the weather in Bangalore and the presence of bio-lakes and green terraces that generate a suitable micro-climate, The main objective was to motivate the employees to utilize terrace gardens as outdoor work areas and for socializing, which raised concerns about the necessity of air conditioning that would lead to fully enclosed interior spaces.

The projected air conditioning system consists of two or three stages and aims to reduce energy usage by 30% compared to traditional systems. This system relies on constant air circulation and is paired with highly efficient HVLS fans (High Volume Low Speed) that consume approximately 20 Watts of electricity while generating 200% more air volume than a 60-watt household ceiling fan [86].

The installation of solar panels is intended for the balconies on the western side and the service on the ground level, which helps to generate electricity to meet 25% of the energy need.



Figure 4.10: Titan Integrity Campus From The Top [82].

Table 4.4: Evaluation Of Titan Integrity Campus According To Biophilic Design Patterns Identified By Browning Et Al [15] [16].

No	Biophilic design pattern	Status	Description with photos
1	Visual connection with nature	✓	 The users of offices through wall glasses, terraces, and outdoor areas are in direct contact with nature in the environment, like water plants, and landscape.
2	Non-visual connection with nature	✓	 The presence of water creates some reflections of sounds that can be received by the employees even though they are in the offices.

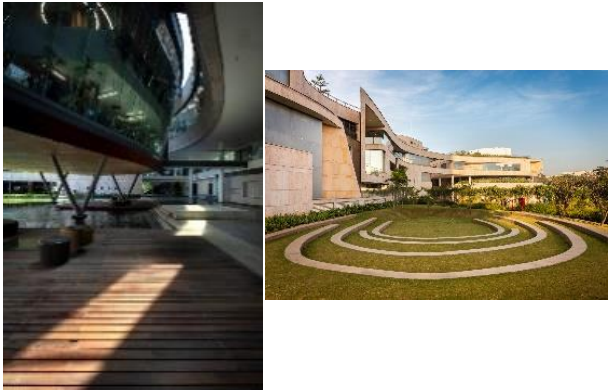
Table 4.5: Evaluation Of Titan Integrity Campus According To Biophilic Design Patterns Identified By Browning Et Al [15] [16] "Table Continued".

3	Non-rhythmic sensual stimuli	✓	 The offices, with glass windows and views of nature, face many non-rhythmic changes, such as cloud movements, birds flying, or insects.
4	Thermal and airflow variability	✓	 The designs featuring unobstructed terraces facilitate more airflow into the indoor spaces. Porosity in planning, using the atriums, and form enables the uninterrupted flow of breezes, as wind tunnels generate a venturi effect.
5	Presence of water	✓	 The bio lake is situated on the eastern side of the land, in direct correlation with the preexisting lake. Expands to the most places of the landscape of the office.

Table 4.6: Evaluation Of Titan Integrity Campus According To Biophilic Design Patterns Identified By Browning Et Al [15] [16] "Table Continued".

6	Dynamic and diffused light	✓	 The five atriums that vertically link all levels, including the basement, allow natural light to permeate throughout.
7	Connection to the natural system	✓	 The design considers the weather conditions in the city, including suitable plants, terraces, the water to make balance with the local climate in the city.
8	Biomorphic forms and patterns	✓	 The form of the building reflects the inspiration taken from the free flow form of the lake as well as the green terraces act as a relaxing space.

Table 4.7: Evaluation Of Titan Integrity Campus According To Biophilic Design Patterns Identified By Browning Et Al [15] [16] "Table Continued".

9	Material connection to nature	✓	 Using Stone and wood materials in the landscape.
10	Complexity and order	-	
11	Prospect	✓	 The raised platform with open space on the ground floor provides unobstructed views.
12	Refuge	-	
13	Mystery	-	
14	Risk/Peril	-	
15	Awe	✓	 Standing at the top of the terraces of Titan, giving the feeling of Awe, because of the height created like a mountain.

Titan employees express their satisfaction with their new environment, highlighting improved comfort, innovative thinking, and enriched talks. The balance between collaboration and seclusion is efficiently maintained, allowing employees to choose their

preferred outdoor places for meetings or personal leisure. The incorporation of natural components, such as grass and fresh air, enhances the overall well-being of the workers [86].

This favorable atmosphere has increased enthusiasm, drive, and overall contentment with the work environment. Titan's pioneering design approach improves employee well-being and demonstrates the company's dedication to fostering innovation and tackling social challenges. Titan has transformed its physical space by adopting biophilic principles, stimulating creativity, and establishing a higher benchmark for office spaces [86].

Prashanti Rao, Somaina Islary, and Kapil Natawadkar [102] conducted a study to evaluate the impact of the Titan Integrity Campus on its users. Their research revealed significant psychological, ecological, and comfort benefits of the campus. Green terraces provide an opportunity to be outdoors and engage with the plants and animals. They also provide paths for enjoyable strolls. The alteration in the atmospheric conditions reinvigorates the senses by introducing an element of unexpectedness.

According to [102] the results of the surveys also express that the green vertical garden on the western side of the building protects the functional spaces from the intense rays of the sun coming from the west. and effectively blocks radiation between the green wall and usable spaces, while the terraces also provide insulation to the workplace areas [102].

The Impact of using biophilic design in Titan campus on Sustainability

The building implemented the following techniques to minimize its influence on the natural environment:

- a. From the site planning perspective: The preexisting trees were safeguarded during construction, while 411 trees were added. The protected topsoil was fenced off, and temporary seeding was carried out to maintain fertility [85].
- b. Water Management The installation of water-efficient low-flow fixtures has reduced the building's water consumption by 59.45% compared to the GRIHA base case, significant decrease of 62% in landscape water needs has been achieved by implementing highly efficient drip and sprinkler irrigation systems, compared to the GRIHA base case.
- c. Energy Optimization: 60.96% of the liveable areas are illuminated by natural daylight and comply with the daylight parameters specified by the National Building Code of India.
- d. Low-energy materials were employed for 83.5% of the ceiling, wall panelling, internal and partitioning, some blocks were utilized to construct both load-bearing and non-load-bearing walls, which consisted of 68% fly ash by volume [85].

4.2 CASE STUDY 2 AMAZON SPHERES

The Amazon Spheres, built in 2018, are a structure housing the headquarters of the Amazon company. Located in Seattle, Washington. The structure won the Best of Design Award 2018 from the Architects' Newspaper [87].



Figure 4.11: Amazon Spheres Office [89].

The concept of this workplace was in mind by the architectural firm NBBJ and the landscaping company Site Workshop. Figure 4.11 illustrates a structure comprising three intersecting spherical domes. The inner core of the construction is constructed using concrete, while the exterior frame is coated with glass. The steel frame of the spheres is made from a pentagonal hexecontahedron, a geometric pattern. The structure is then covered with 2,643 glass panels [89].

Initially, this structure was called the “Canter of Energy,” but the Spheres were envisioned as where Amazonians might retreat from the urban design. Returning from the typical office environments and noise, employees use this workspace as a place to get motivation and being energized [90].

The spheres, which range in height from 24 to 29 meters, function as both a lounge and workspace for employees. Metal constructions exhibit greater fluidity within glass walls, preferring curved forms over sharp edges. The spheres is a four-floor structure with a total

area of 299.6 square meters. It accommodates the cafeteria, staircases, elevators, and restrooms.



Figure 4.12: Amazon Spheres From The Top [93].

The transparent exterior of the spheres depicted in Figure 4.12 permits the ingress of natural light, establishing a relationship between the inner space and the surrounding natural environment. The Spheres feature a translucent façade that seamlessly blends with the environment, allowing employees direct visual contact with nature. This design reflects the seamless integration of nature within the area [96].

The team of the designers introduced the name "Catalan" to designate the specific pattern found within each pentagon. The original Catalan pattern comprised rectangular box parts that were curled in both directions with continuously variable curvatures and twisted around their axis [90].



Figure 4.13: The First Inspiration Object Of The Catalan Pattern Used In Amazon Spheres [90].

After an extensive examination of architectural and structural concepts considering the geometrical and mathematical theories about spheres and shell structures, the design team drew inspiration from a lampshade as shown in 4.13. One team member observed a spherical light adorned with a recurring organic design, which another team member identified as being inspired by a mathematical idea called a Catalan solid. Eugene Charles Catalan, a mathematician from France and Belgium, invented these solids in the late 1800s. This revelation prompted the researchers to explore the concept further. After considering other alternatives, they ultimately selected a spherical structure of 60 pentagons of the same size and shape. This structure is called a pentagonal hexecontahedron or a Catalan solid with 60 faces [90].

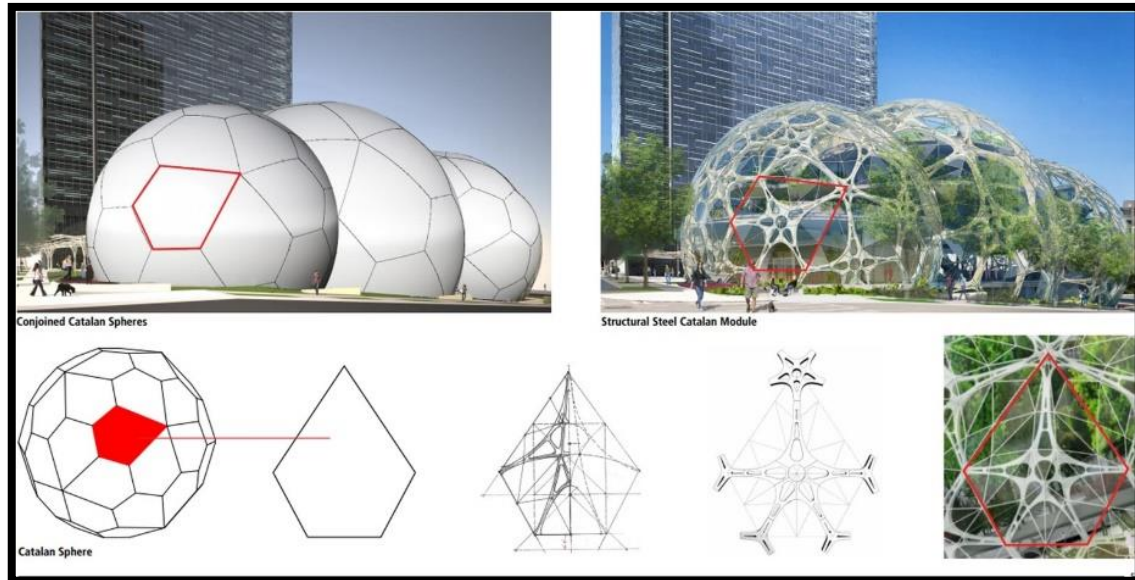


Figure 4.14: Photo Using Nature Inspiration In The Pattern Of The Amazon Sphere's Structure [98].

The Director of NBBJ, Dale Alberda, has expressed that the design team is currently focused on developing a "hybrid environment" that fosters productivity and collaboration. This approach is based on recent studies indicating that the human brain performs optimally in natural surroundings. The Spheres allow employees to work in a workspace seamlessly linked with nature, fostering a profound and advanced connection between humans and the natural environment [94].

The central sphere, which is the largest, has a height of four floors and covers an area of 299.6 square meters. It contains a restaurant, staircases, elevators, and bathrooms. The stairway is adorned with a vertical garden spanning four stories, known as a "living wall," which consists of some 25,000 plants.

This includes many carnivorous species native to Asia. Figure 4.15 illustrates that the wall completely encloses the elevator shaft, providing an unobstructed view from the top to the bottom as you climb the entrance stairs. This view is visible from every level of the four levels [99].



Figure 4.15: The Green Wall In Amazon Spheres Office [96].

Spheres utilize a sophisticated ventilation system to guarantee the flow of uncontaminated air. The ventilation ducts in the plant wall seen in Figure 4.15 (on the left) enable the downward circulation of air and expel it circularly to enhance its movement. The water mists seen in Figure 4.15 (on the right) provide nutrients to the plant walls, promote the well-being and development of plants, and enhance the microclimate within the indoor environment. [89].

The temperature and humidity restrictions in Amazon Spheres are carefully designed to cater to the specific biological requirements of the flora and interior environment. Plants achieve optimal photosynthetic rates and minimize water loss when exposed to a daytime temperature of around 22 degrees Celsius and a humidity level of 60%.

At night, the temperature decreases to approximately 13 degrees Celsius, with a humidity level of nearly 90% [89]. These conditions are favorable for the nighttime respiration and moisture needs of plants. The optimal combination of temperature and humidity facilitates the healthy development and metabolic functions of plants while also promoting biophilic experiences and ensuring human comfort indoors [93].



Figure 4.16: The Airflow System In Amazon Spheres [95].

Spheres contain a substantial waterfall on its grounds. This waterfall replicates the natural flow of water and generates a tranquil ambiance within the indoor environment. Amazon procured the stones utilized in the fabrication of the waterfall, as depicted in Figure 4.17, from nearby stone quarries in Eastern Washington, so including a natural element and satisfying the tenet of water inclusion in biophilic design [99].



Figure 4.17: The Waterfall In The Amazon Spheres [88].

The presence of waterfalls and densely populated living walls evokes the atmosphere of a jungle. To maintain optimal conditions for the plants, the temperature within the Spheres is maintained at 72 degrees Fahrenheit, and the humidity is kept at 60 percent during the day. However, during the night, the temperature is lowered to 55 degrees while the humidity is increased to 90 percent. The Spheres, covering an area of 67,000 square feet, are a mere two percent of the Amazon project. However, they function as a compelling force that brings

people together. Available exclusively to Amazon employees, this facility provides a variety of spaces for meetings, work, and dining. These spaces include a wooden-slatted "bird nest" and terraces with banquettes and chairs [89].

The curved structure of the Amazon Spheres redirects the varying sunlight into the interior from various perspectives during the day, resulting in a dynamic illumination effect within the area. This method creates a dynamic and lively space that undergoes constant change and vibrancy over time. It also offers various visual experiences throughout the day, depending on the direction and intensity of light, improving the space's vitality. Using automatic lighting control systems enhances and strengthens the dynamic lighting experience [96].

According to facility manager Justin Schroeder, the glass utilized on the outer facade of Spheres prevents infrared heat and ultraviolet light from entering, ensuring staff comfort. As a result, the lighting inside the area is specifically intended to reintroduce the red-blue spectrum required for plant growth. A total of 150 lights have been deliberately positioned around the structure to cater to the specific requirements of the plants in the surrounding environment. The presence of light-sensitive cells enables the perception of more excellent light on cloudy days and lower light on sunny days. This facilitates a seamless transition between the indoor and natural environments, allowing personnel to observe temporal variations [99].

According to Mike Fong, the gardening specialist involved in the Spheres project, numerous experiments were carried out to identify the positions that do not result in light glare affecting people's vision. Figure 4.18 illustrates that the lights positioned around the steel frame of the spheres are oriented toward the plants rather than people [96].



Figure 4.18: Photos Of The Lighting System In Amazon Spheres [97].

The Canopy Walk is a wooden walkway hanging 25 meters above the ground. It is designed to ring the Rubi tree, the most giant tree in the Spheres. Figure 4.19 and Figure 4.20 illustrate multiple locations along the route where individuals can pause and appreciate the landscape, providing employees with a comprehensive perspective of the tree and its environment [89].



Figure 4.19: The Canopy Of Amazon Spheres [88].



Figure 4.20: The Corridor In Amazon Spheres Which Goes To The Canopy [96].

Another of these points is the shared workspace integrated into the Canopy Walk, as seen in Figure 5.19 Constructed from sustainable and sturdy black acacia wood, resembling a bird's nest, it provides a unique area for collaboration. Special spaces as in Figure 4.20 created with materials found in the natural environment provide a sense of nature indoors throughout the structure [99].

On the third floor of the Spheres, there is a quiet corner equipped with loungers where employees can lean back and enjoy the sun. This area, referred to as the "sunbathing terrace" by Amazon officials and depicted in Figure 4.21, allows employees to take a break from their main activities, relax their minds, and benefit from sunlight [96].



Figure 4.21: The Sunbathing Terrace In Amazon Spheres [91].

It is widely recognized that engaging with nature elicits a profound sense of exploration in individuals. Figure 4.22 depicts the preference for organic forms over straight lines in circulation zones within the Spheres. Utilizing meandering pathways engenders a feeling of

becoming disoriented amidst the natural surroundings, cultivating inquisitiveness with the contemplation of "what will I chance upon at the next turn?" The design incorporates concealed sightlines and an aura of enigma, mirroring the emotions created by nature in the spatial arrangement [96].



Figure 4.22: Some Corridors In The Spheres [95].

The Amazon Spheres include a harmonious micro-ecosystem replicating the plant life and climate conditions of its specific geographic area. The structure is designed to prioritize adaptation to the local climate and natural surroundings by incorporating tropical plants, as depicted in Figure 4.23, which draws inspiration from rainforests [96].



Figure 4.23: Examples Of Various Plants Used In Amazon Spheres Offices [96].

The impression of hazards or threats encountered in natural environments elicits a specific degree of vigilance in human beings. The suspended wooden setting area on the third floor of the Spheres is designed to make people feel danger. in Figure 4.24. This design elicits a sense of risk and danger in the user [96].

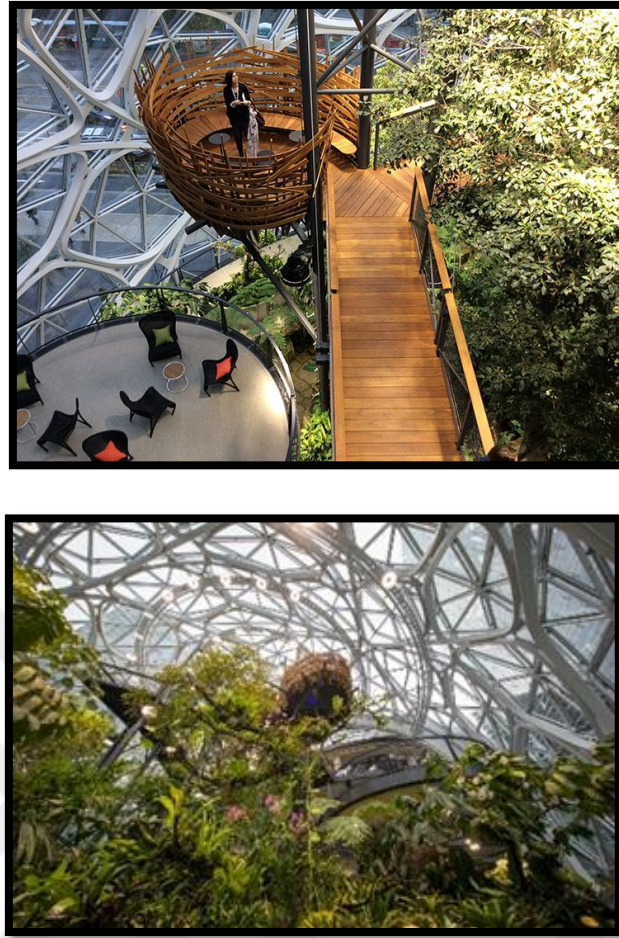


Figure 4.24: The Suspended Setting Area In Amazon Spheres [88].

According to the findings in Table 4.4, all the biophilic design criteria from the biophilic design model prepared by Browning et al. [15] were identified in the Amazon Spheres building.

Table 4.8: Evaluation Of Amazon Spheres Office According To Biophilic Design Patterns Identified By Browning Et Al. [15] [16].

No	Biophilic design pattern	Status	Description with photos
1	Visual connection with nature	✓	 It can be observed that the spherical- The glass facades of the building connect office workers to nature, even in outdoor spaces.

Table 4.9: Evaluation Of Amazon Spheres Office According To Biophilic Design Patterns Identified By Browning Et Al. [15] [16] "Table Continued".

2	Non-visual connection with nature	✓	 The sound of water flowing from the indoor waterfall and the scent of flowering plants are essential factors that enrich individuals' sensory experiences. The spheres use elements referencing natural systems with auditory, tactile, and olfactory stimuli to emphasize the function of natural processes.
3	Non-rhythmic sensual stimuli	✓	 The aquarium and live animals create some nonrhythmic sensual stimuli as well as the movement of tree and plant leaves can be observed.
4	Thermal and airflow variability	✓	 During the daytime, the spheres are set to approximately 22 degrees Celsius temperature and 60% humidity, while at night, they are adjusted to around 13 degrees Celsius temperature and 90% humidity.

Table 4.10: Evaluation of Amazon Spheres Office According to Biophilic Design Patterns Identified by Browning et al. [15] [16] "Table Continued".

5	Presence of water	✓	 The Spheres feature a waterfall within their structure. This waterfall not only naturally mimics water flow in nature but also creates a soothing atmosphere indoors.
6	Dynamic and diffused light	✓	 The dome shape of the Amazon Spheres reflects sunlight into the interior from different angles, creating a dynamic lighting effect throughout the space that varies with the time of day. This dynamic lighting experience is further enhanced by automatic lighting reinforcement.
7	Connection to the natural system	✓	 The building, designed inspired by rainforests, emphasizes the local climate and natural environment by using tropical plants.

Table 4.11: Evaluation Of Amazon Spheres Office According To Biophilic Design Patterns Identified By Browning Et Al. [15] [16] "Table Continued".

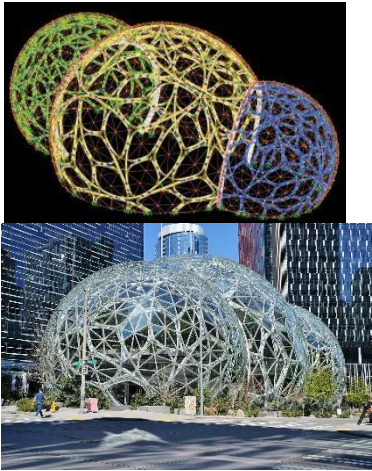
8	Biomorphic forms and patterns	✓	 It is observed that the design explored from natural geometrics is a spherical shape consisting of 60 pentagons that are similarly sized and shaped. These pentagons are arranged around a dual-polyhedron Catalan solid, specifically a pentagonal hexecontahedron.
9	Material connection to nature	✓	 Patterns and compositions from nature have been transferred to the interior of the Spheres using a symbolic approach. Embedded linear lighting designed in a form resembling tree branches presents a symbolic example of biomorphic forms and patterns.
10	Complexity and order	✓	 Fractal geometry and hierarchy found in nature have been translated into design in a visually, formally, and spatially similar manner to obtain nature-inspired associations.

Table 4.12: Evaluation Of Amazon Spheres Office According To Biophilic Design Patterns Identified By Browning Et Al. [15] [16] "Table Continued".

11	Prospect	✓	 Mezzanines positioned to encircle the Rubi tree, referred to as the largest inhabitant of the Spheres, have several points where one can stop and enjoy the scenery, providing employees with a full view of the tree and its surroundings.
12	Refuge	✓	 Amazon officials have named the area they provided a "sunbathing terrace," allowing employees to take a break from their main activities and relax their minds while enjoying the sunlight.
13	Mystery	✓	 In the circulation areas of the Spheres, organic forms have been preferred over straight lines. Curving paths create a sense of getting lost in nature, sparking curiosity with the thought of "what will I encounter around the corner," and creating mystery with hidden perspectives, reflecting the spatial design inspired by nature's ambiance.

Table 4.13: Evaluation Of Amazon Spheres Office According To Biophilic Design Patterns Identified By Browning Et Al. [15] [16] "Table Continued".

14	Risk/Peril	✓	 The suspended setting area on the third floor of the Spheres is designed to make people feel danger.
15	Awe	-	

Contemporary workplaces have evolved beyond passive environments where employees occupy their workstations for five consecutive days. The ecosystem is characterized by thoughtfulness, flexibility, and activity and is constructed around a diverse range of options and the ability to make independent choices. Workspaces offering a diverse range of options and promoting "in-office mobility" demonstrate better effectiveness and satisfaction. These elements are crucial in determining the real estate strategy of firms like Amazon, which has more than 45,000 employees in Seattle alone [98].

According to research conducted by SP Perrins et al. [101], workers in Amazon spheres, including 153 participants, participated in a survey that examined the relationship between reported visits to an indoor workplace greenspace and psychological well-being, which includes symptoms of sadness, anxiety, positive and negative emotions, and stress.

It was found that interacting with natural outdoor environments had a strong impact on reducing state anxiety, stress, and negative feelings. [101].

The study findings indicate a strong correlation between regular social interactions and reduced levels of anxiety [101].

The Impact of using biophilic design in Amazon spheres on Sustainability

Below the abundant vegetation lies a clever irrigation system that distributes water throughout the vertical gardens, guaranteeing ideal moisture levels for the plants. Surplus

water is intelligently redirected to a central reservoir, reducing wastage, and encouraging resource conservation.

Building materials maker Holcim asserts that using construction materials and techniques for The Spheres reduced over 400 tonnes of CO₂ emissions [97].

The building of Amazon in Seattle has included green roofs, which offer numerous advantages, including:

- a. Reducing the need for heating and cooling.
- b. Stormwater runoff can be filtered and reduced by up to 70%.
- c. Alleviating the urban heat island phenomenon.
- d. Improving the air quality in the immediate vicinity.
- e. Maximizing energy efficiency and promoting responsible utilization of resources:
- f. Amazon's sustainable buildings are furnished with Wood resources that have been previously used and procured from nearby locations Possibilities for composting and recycling [100].

On September 19, 2019, Amazon declared its commitment to achieving the goals of the Paris Agreement a decade ahead of schedule. The main objectives are to achieve complete carbon neutrality by 2040, Attain 80% renewable energy by 2024, reach 100% renewable energy and ensure that 50% of shipments are carbon neutral by 2030 [100].

5. RESULTS

The research focused on evaluating chosen offices from an interior architectural standpoint to analyze the implementation of the 15 principles of biophilic design suggested by Browning et al., [15][16] in spatial design. The comprehensive evaluation, taken from the compilation of assessment tables from Chapter 4 , is displayed in Table 5.1. Using the general assessment table and the biophilic design principles outlined by Browning et al., [15][16] a comprehensive evaluation was conducted for two offices under investigation:

Two awarded office buildings (Titan integrity campus and Amazon spheres offices), received awards as part of our field investigations. Our analysis was based on the criteria specified in the biophilic design model developed by Browning et al [15][16].

The main findings from the case studies in the previous section indicate that:

The Amazon Spheres contained 14 out of 15 of the patterns stated in Browning et al except the pattern of Awe.

While the Titan Integrity Campus, 12 out of 15 elements from the biophilic design model developed by Browning et al [15][16] were implemented, except for the concepts of complexity, mystery, refuge, and risk/danger.

Table 5.1: Collective Assessment Table Of Office Buildings According To Biophilic Design Criteria Determined By Browning Et Al.

Biophilic design pattern		Offices	
		Titan Integrity campus	Amazon spheres
Nature in space	Visual Connection with Nature	✓	✓
	Non-visual connection with Nature	✓	✓
	Non-Rhythmic Sensory Stimuli	✓	✓
	Thermal and airflow Variability	✓	✓
	Presence of Water	✓	✓
	Dynamic & Diffuse Light	✓	✓
	Connection with Natural Systems	✓	✓
Natural Analogue	Biomorphic Forms & Patterns	✓	✓

Table 5.2: Collective Assessment Table Of Office Buildings According To Biophilic Design Criteria Determined By Browning Et Al "Table Continued".

	Material Connection with Nature	✓	✓
	Complexity & Order	-	✓
Nature of space	Prospect	✓	✓
	Refuge	-	✓
	Mystery	-	✓
	Risk	-	✓
	Awe	✓	-

It is evident that when an office plans to incorporate a biophilic design, it is not obligatory to incorporate all the ideas or features of this approach entirely. Alternatively, design ideas might be chosen or systematically included based on the area's particular needs and financial resources. This exemplifies the adaptability of biophilic design. The concept of "flexibility in biophilic design" refers to the capacity of biophilic design to adjust and conform to various circumstances, environments, and financial constraints. This statement highlights that biophilic design is not reliant on inflexible and unchanging principles but is a design methodology that can be adjusted to accommodate different factors.

From the case studies and the surveys conducted by researchers to users of these buildings, we can conclude that Spaces constructed with a biophilic approach enable humans to cultivate a more intimate connection with nature and experience the sensation of being in a natural setting indoors. Hence, it is imperative to incorporate biophilic design principles into the architectural design process to promote human health and well-being.

The data found, demonstrate that the biophilic design approach has a high potential for enhancing human well-being. The Integrity campus and Amazon spheres exemplify how the biophilic design approach not only enhances the visual appeal of buildings but also dramatically improves the health and well-being of workers, providing them with a distinctly new identity. On the other hand, the examination of the offices applying biophilic design showed us how Biophilic design can enhance sustainability in architecture through several means. Upon examining the distinct difficulties faced by sustainable buildings and the numerous advantages of biophilic design, we have discovered that the majority of the benefits of biophilic design directly or indirectly address these obstacles.

Table 5.2 thoroughly examines the distinct sustainable practices and commitments of both the Amazon Spheres and the Titan Integrity Campus. It highlights their endeavors to promote environmental responsibility and conserve resources.

Table 5.3: Comparative Analysis Of Sustainable Benefits Between Titan Integrity Campus And Amazon Spheres.

Sustainable benefits	Titan Integrity Campus	Amazon Spheres
Preservation of Resources	Tree preservation and planting	Efficient irrigation system for vertical gardens
	Water-efficient fixtures, reducing usage by 59.45%	Green roofs for energy efficiency, stormwater purification
	Reduced water consumption during construction	Efficient water diversion to a central reservoir
Energy Efficiency	Natural sunlight for 60.96% of habitable areas	Implementation of district energy systems, LED lighting
	Use of occupancy sensors and digital timers for lighting control	Utilization of occupancy sensors, optimization of natural light
	Extensive use of low-energy materials	Incorporation of repurposed wood supplies
Carbon Emissions Reduction	Use of low-energy materials, including fly ash blocks	Reduction of over 400 tonnes of CO ₂ emissions during construction
Agreement Commitment	Commitment to enduring environmental sustainability	Commitment to carbon neutrality, renewable energy goals

The emergence of biophilic design in recent years is a response to the deteriorating interaction between humans and nature. Biophilic design focuses on the connection between humans and the natural world. Hence, eco-friendly structures have been erected by the biophilic design principle to reestablish a connection between individuals and the natural world. Certain buildings exhibit a strong integration with nature, while others strive to include nature in their design, either directly or indirectly.

After the selected office buildings in terms of biophilic design features, a literature review related to the concept of biophilic design was conducted. Its relationship with sustainability goals was addressed, and then the concept of offices and office buildings was addressed. The ergonomic factors in office design are discussed. The hypotheses regarding the selected

office buildings as the application area of the determined biophilic design criteria were answered based on the literature review conducted:

a. What are the contributions of direct and indirect contact with nature in the built environment to human health? How do the employees receive and act after integrating biophilic design elements into their workplace environment?

As seen direct and indirect contact with nature in the built environment has positive psychological and physical effects on human health.

It has been observed that understanding biophilic design can increase the level of well-being in human life. Designing indoor spaces with the biophilic approach can benefit users positively. It is possible to say that with the biophilic design approach, indoor air quality can be excellent, and shading, climate control functions, and aesthetic effects in indoor spaces can be increased. Additionally, it has been concluded that it can also benefit the staff's productivity.

b. Does implementing biophilic design patterns create more environmentally sustainable office space?

It has been observed that there is a strong relationship between biophilic design and sustainability. They complement each other and have mutual goals regarding human needs in the present and future. The findings from the examined offices emphasize the benefits of integrating biophilic design patterns to build more sustainable buildings.

The biophilic design approach has been found to enhance the overall quality of human life potentially. Implementing biophilic design in interior settings might yield advantageous outcomes for users. The implementation of a biophilic design strategy has the potential to significantly enhance indoor air quality, as well as improve shading, climate control functions, and aesthetic effects within interior spaces. Furthermore, it has been determined to yield advantages regarding the staff's job productivity.

The study focused specifically on internationally renowned office structures. The study found that the award-winning office buildings successfully fulfilled the biophilic design requirements and connected directly or indirectly with the natural environment. Biophilic design is considered a crucial component of sustainability. Hence, it was imperative to ensure sustainability when designing office buildings. The construction of the buildings was undertaken with an environmental perspective, in addition to enhancing the area's aesthetic appeal.

Prior research has demonstrated that integrating biophilic design features into office environments positively impacts employees' productivity, focus, and emotional state. Hence, incorporating natural features into workplace space design is advantageous for enhancing the quality of life. Several readily implementable applications have been suggested to enhance the incorporation of natural components in the work environment, including:

Incorporating living plants into the workplace. Using natural objects, particularly in the design of workplace spaces. Utilizing organic materials such as leather, timber, and cotton. Design shapes and structures that imitate organic patterns to enhance the office environment and employee comfort, one can opt for locations that receive ample sunlight or use lighting fixtures that replicate natural light, ensuring sufficient daylight.

Integrating biophilic design in workplace buildings has a major impact on human well-being. These contributions include enhanced productivity, willingness, and attentiveness of employees, along with improved the mental health.

However, after urbanization and when individuals are becoming more detached from nature, it is necessary to implement design techniques that promote reconnection with the natural world and benefit from the impact of biophilic design components on human well-being, it is important to include these aspects in the built environment, particularly in workspaces such as offices.

6. DISCUSSION AND CONCLUSION

This paper thoroughly examines the concept of biophilic design, including its origins, definition, and potential contributions to sustainable architecture. Additionally, it covers the essential design techniques associated with biophilic design. Initially, the paper examined the foundational principles and many significant analyses of biophilic design. Next, the study linked the different advantages of biophilic design with the numerous obstacles in sustainable architecture. Furthermore, proposed a biophilic design framework and assembled design solutions, collecting the advantages and disadvantages of many natural architectural elements.

Office buildings are the primary locations where employees dedicate most of their time. Hence, the design of office buildings should emphasize optimal comfort conditions and customized spatial arrangements for users. The literature review undertaken as part of this study also highlights that interacting with nature benefits individuals' psychology and improves productivity in workplace settings. To create more optimal working environments in office settings, it is advisable to incorporate design strategies that allow employees to engage with nature, given the numerous advantages of such interactions.

Biophilic design incorporates design principles that positively impact human health and psychology, giving employees relaxation, motivation, and productivity. Therefore, it is feasible to design spatial layouts that avoid giving office workers the sensation of being confined in isolated, enclosed spaces for the day. Based on the analysis of office buildings, it is evident that implementing the biophilic design approach leads to the creation of spatial elements that are more comfortable, promote better health, and enhance productivity for users. Hence, it is imperative to integrate biophilic design strategies into the architecture of office buildings to offer users enhanced comfort, stress management, and improved work productivity.

This research proves that integrating biophilic design into office buildings enhances employee well-being and the performance of organizations and companies. Creating a more positive and conducive work environment can decrease employee stress, enhance productivity, motivation, and efficiency, and ultimately reinforce the business brand. It is believed that as firms recognize the significance of creating innovative environments that

enhance employees' concentration and productivity, the adoption of biophilic design will become more prominent.

On the other hand, the study and literature review conducted underlined some negative effects of biophilic design elements. These include issues such as lack of distribution of light, glare, high temperatures, or overheating resulting from poorly organized daylight utilization. Furthermore, neglecting regular maintenance of water elements or plants could lead to pollution. It's important for engineers to know about acoustic management, especially concerning water features or animals within interior spaces, to avoid such problems. Additionally, attention should be given to biophobic phenomena that may cause discomfort in individuals. The patterns of risk, awe, and mystery should also consider the psychological discomfort they may affect the users.

Biophilic design is a tool and a practical methodology for creating the built environment, focusing on human values and the sustainability of the natural world. The primary objective of this technique is to enhance and strengthen the connections between humans and the natural environment, allowing for the opportunity to engage with nature inside constructed surroundings. Integrating biophilic components into constructed habitats enhances the connection between humans and nature, promoting their physical and psychological well-being.

Within spatial design, rigorous adherence to the principles of specific design styles often results in spaces that lack a connection to the human and natural essence. Designers and architects have the responsibility to safeguard human physiological and psychological well-being and promote the cause of nature.

This thesis aims to raise awareness by emphasizing the significance of nature as a lasting source of inspiration for architecture and drawing attention to the encounter with nature in constructed spaces. It focuses on the beneficial impact of experiencing nature on human psychology and physiology. Our objective is to encourage the extensive implementation of biophilic design in office buildings throughout our nation.

Given the alarming rates of global population growth and urbanization, implementing biophilic design in office buildings is not just a choice but a necessity. As natural resources are nearing exhaustion, we must act now to ensure a sustainable and healthy future for all.

6.1 RECOMMENDATIONS

Designers need knowledge from different fields of study to select appropriate design strategies based on their goals and expected outcomes, including potential physical and psychological reactions. However, much of the previous research on the benefits of biophilic design overlooks its diversity, failing to connect impacts with practical elements. This generalized approach obscures the variety of biophilic design approaches and elements, hindering its practical implementation. Additionally, applying these elements requires expertise from various architectural subfields, such as materiality, tectonics, mechanical systems, and mobility, often overlooked in biophilic design studies. Therefore, it is crucial to align design objectives with specific biophilic design elements and involve specialists from relevant fields in guideline development.

The biophilic design framework comprises separate yet interconnected aspects. The categorization of biophilic design is not rigid, and the various parts within it are often interconnected. To incorporate plants into buildings, it is crucial to consider factors such as water, air, sunlight, animals, weather, and seasons to sustain plant life. Additionally, it is essential to regularly prune plants to promote their growth, establish sheltered areas with tree canopies, utilize native plant species to foster a connection with the local environment, meticulously design transitional spaces between indoor and outdoor areas to avoid disruptions to the entire ecosystem and consider various other aspects.

Overall, the analysis underscores the importance of integrating biophilic design principles into architectural practice to create healthier, more sustainable, and aesthetically pleasing built environments. However, it also emphasizes the need for interdisciplinary collaboration and careful consideration of potential drawbacks to ensure successful implementation. Further research and innovation in this field are warranted to address remaining challenges and maximize the benefits of biophilic design for both occupants and the natural environment.

Our recommendations are to develop educational programs and workshops for architects, designers, and construction professionals to raise awareness and provide the necessary skills for implementing biophilic design.

Work towards making biophilic design a standard practice in office buildings across Turkey. This can be achieved by integrating these principles into building codes and regulations.

Include ISO 14100 standards in biophilic design studies and implementations. This international standard provides guidelines for environmental management systems, ensuring that biophilic design aligns with globally recognized sustainability practices.

6.2 FUTURE RESEARCH

Biophilic design is still relatively new, leaving many questions unanswered. While biophilic design inspires architects, we need better ways to talk about it in terms of building types, organization, and context. Moving forward, researchers should look at buildings from an architectural perspective, considering how they are built, their shape, the technology used, and how they are shown. Questions to explore include: How does biophilic design change building shapes? How can we talk about it in terms of different building types? How does it affect how spaces are arranged? How does it fit into the location and surroundings? There are no clear guidelines for using biophilic design in architecture, so more research is needed to figure that out.

Although the theories and data analyzed in this thesis establish a foundation for implementing the biophilic design in office settings, additional study is required to explore this field further. Future academic studies should prioritize highlighting the beneficial impacts of the biophilic design approach in workplace environments and examining and addressing any potential adverse effects and obstacles. Therefore, it is possible to establish biophilic design applications for various functional structures, resulting in developing a comprehensive guide.

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APPENDIX A

BIOPHILIC DESIGN PATTERNS & BIOLOGICAL RESPONSES SOURCE [110].

Table 1 demonstrates the roles of the 14 Patterns in promoting stress reduction, enhancing cognitive performance, improving emotion and mood, and benefiting the human body. Patterns that have strong empirical evidence supporting them are denoted by up to three asterisks (***)

14 PATTERNS	* STRESS REDUCTION	COGNITIVE PERFORMANCE	EMOTION, MOOD & PREFERENCE	
NATURE IN THE SPACE	Visual Connection with Nature	Lowered blood pressure and heart rate (Brown, Barton & Gladwell, 2013; van den Berg, Hartig, & Staats, 2007; Tsunetsugu & Miyazaki, 2005)	Improved mental engagement/ attentiveness (Biederman & Vessel, 2006)	Positively impacted attitude and overall happiness (Barton & Pretty, 2010)
	Non-Visual Connection with Nature	Reduced systolic blood pressure and stress hormones (Park et al., 2009; Hartig, Evans, Jamner et al., 2003; Orsega-Smith et al., 2004; Ulrich et al., 1991)	Positively impacted cognitive performance (Mehta, Zhu & Cheema, 2012; Ljungberg, Neely, & Lundström, 2004)	Perceived improvements in mental health and tranquility (Li et al., 2012; Jahncke, et al., 2011; Tsunetsugu, Park, & Miyazaki, 2010; Kim, Ren, & Fielding, 2007; Stigsdotter & Grahn, 2003)
	Non-Rhythmic Sensory Stimuli	Positively impacted heart rate, systolic blood pressure and sympathetic nervous system activity (Li, 2010; Park et al., 2008; Kahn et al., 2008; Beauchamp, et al., 2003; Ulrich et al., 1991)	Observed and quantified behavioral measures of attention and exploration (Windhager et al., 2011)	
	Thermal & Airflow Variability	Positively impacted comfort, well-being and productivity (Heerwagen, 2006; Tham & Willem, 2005; Wigö, 2005)	Positively impacted concentration (Hartig et al., 2003; Hartig et al., 1991; R. Kaplan & Kaplan, 1989)	Improved perception of temporal and spatial pleasure (alliesthesia) (Parkinson, de Dear & Candido, 2012; Zhang, Arens, Huizenga & Han, 2010; Arens, Zhang & Huizenga, 2006; Zhang, 2003; de Dear & Brager, 2002; Heschang, 1979)
	Presence of Water	Reduced stress, increased feelings of tranquility, lower heart rate and blood pressure (Avarsson, Wiens, & Nilsson, 2010; Pheasant et al., 2010; Biederman & Vessel, 2006)	Improved concentration and memory restoration (Avarsson et al., 2010; Biederman & Vessel, 2006) Enhanced perception and psychological responsiveness (Avarsson et al., 2010; Hunter et al., 2010)	Observed preferences and positive emotional responses (Windhager, 2011; Barton & Pretty, 2010; White et al., 2010; Karmanov & Hamel, 2008; Biederman & Vessel, 2006; Heerwagen & Orians, 1993; Russo & Atzwanger, 2003; Ulrich, 1983)
	Dynamic & Diffuse Light	- Positively impacted circadian system functioning (Figueiro et al., 2011; Beckett & Roden, 2009) - Increased visual comfort (Elyezadi, 2012; Kim & Kim, 2007)		
	Connection with Natural Systems			Enhanced positive health responses; Shifted perception of environment (Kellert et al., 2008)
NATURAL ANALOGUES	Biomorphic Forms & Patterns			Observed view preference (Vessel, 2012; Joye, 2007)
	Material Connection with Nature		Decreased diastolic blood pressure (Tsunetsugu, Miyazaki & Sato, 2007) Improved creative performance (Lichtenfeld et al., 2012)	Improved comfort (Tsunetsugu, Miyazaki & Sato 2007)
	Complexity & Order	Positively impacted perceptual and physiological stress responses (Salingaros, 2012; Joye, 2007; Taylor, 2006; S. Kaplan, 1988)		Observed view preference (Salingaros, 2012; Hägerhäll et al., 2008; Hägerhäll, Purcella, & Taylor, 2004; Taylor, 2006)
NATURE OF THE SPACE	Prospect	Reduced stress (Grahn & Stigsdotter, 2010)	Reduced boredom, irritation, fatigue (Clearwater & Coss, 1991)	Improved comfort and perceived safety (Herzog & Bryce, 2007; Wang & Taylor, 2006; Petherick, 2000)
	Refuge		Improved concentration, attention and perception of safety (Grahn & Stigsdotter, 2010; Ulrich et al., 1991; Wang & Taylor, 2006; Petherick, 2000)	
	Mystery			Induced strong pleasure response (Biederman, 2011; Salimpoor et al., 2011; Ikemi, 2005; Blood & Zatorre, 2001)
	Risk/Peril			Resulted in strong dopamine or pleasure responses (Kohno et al., 2013; Wang & Tsien, 2011; Zaid et al., 2008)

APPENDIX B

THREE KEY FRAMEWORKS OF BIOPHILIC DESIGN (SOURCES [106], [16] [40]).

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2 Dimensions, 6 Elements, and 72 Attributes of Biophilic Design (Kellert, 2008b)					
I. Organic or Naturalistic				II. Place-based or Vernacular	
1. Environmental features	2. Natural shapes and forms	3. Natural patterns and processes	4. Light and space	5. Place-based relationships	6. Evolved human-nature relationships
• Color • Water • Air • Sunlight • Plants • Animals • Natural materials • Views and vistas • Façade greening • Geology and landscape • Habitats and ecosystems • Fire	• Botanical motifs • Tree and columnar supports • Animal (mainly vertebrate) motifs • Shells and spirals • Egg, oval, and tubular forms • Arches, vaults, domes • Shapes resisting straight lines and right angles • Simulation of natural features • Biomorphy • Geomorphology • Biomimicry	• Sensory variability • Information richness • Age, change, and the patina of time • Growth and efflorescence • Central focal point • Patterned wholes • Bounded spaces • Transitional spaces • Linked series and chains • Integration of parts to wholes • Complementary contrasts • Dynamic balance and tension • Fractals • Hierarchically organized ratios and scales	• Natural light • Filtered and diffused light • Light and shadow • Reflected light • Light pools • Warm light • Light as shape and form • Spaciousness • Spatial variability • Space as shape and form • Spatial harmony • Inside-outside spaces	• Geographic connection to place • Historic connection to place • Ecological connection to place • Cultural connection to place • Indigenous materials • Landscape orientation • Landscape features that define building form • Landscape ecology • Integration of culture and ecology • Spirit of place • Avoiding placelessness	• Prospect and refuge • Order and complexity • Curiosity and enticement • Change and metamorphosis • Security and protection • Mastery and control • Affection and attachment • Attraction and beauty • Exploration and discovery • Information and cognition • Fear and awe • Reverence and spirituality
3 Experiences and 25 Attributes of Biophilic Design (Kellert, 2018)					
1. Direct Experience of Nature	2. Indirect Experience of Nature		3. Experience of Space and Place		
• Light • Air • Water • Plants • Animals • Landscapes • Weather • Views • Fire	• Images • Materials • Texture • Color • Shapes and forms • Information richness • Change, age and the patina of time • Natural geometries • Simulated natural light and air • Biomimicry		• Prospect and refuge • Organized complexity • Mobility • Transitional spaces • Place • Integrating parts to create wholes		
3 Categories and 15 Patterns of Biophilic Design (Browning and Ryan, 2020)					
1. Nature in the Space	2. Natural Analogues		3. Nature of the Space		
• Visual Connection with Nature • Non-Visual Connection with Nature • Non-Rhythmic Sensory Stimuli • Thermal & Airflow Variability • Presence of Water • Dynamic & Diffuse Light • Connection with Natural Systems	• Biomorphic Forms & Patterns • Material Connection with Nature • Complexity & Order		• Prospect • Refuge • Mystery • Risk/Peril • Awe		