THE ECONOMICS OF BIOPHILIA

WHY DESIGNING WITH NATURE IN MIND MAKES FINANCIAL SENSE

– 2ND EDITION –



TERRAPIN

BRIGHT GREEN

"Biophilia is the innately emotional affiliation of human beings to other living organisms... Life around us exceeds in complexity and beauty anything else humanity is ever likely to encounter."

EDWARD O. WILSON

The Biophilia Hypothesis, 1993

"Biophilic design is more complex and richer than the mere application of vegetation in buildings; it broadens the variety through encompassing different types of nature from physical, sensory, metaphorical, morphological, material to spiritual."

ZHONG, SCHRÖDER & BEKKERING

Frontiers of Architectural Research, 2022

Biophilic design in architecture and its contributions to health, well-being, and sustainability: A critical review. Frontiers of Architectural Research, 11(1), 114–141. https://doi.org/10.1016/j.foar.2021.07.006

"...Creating biophilic, sustainable, and wellness-focused spaces isn't just a sound investment. It's doing the right thing."

BRIAN VICKERY

Senior Director, Design and Construction, Four Seasons Hotels and Resorts

in Doing the Right Thing: Why Hotels Are Embracing Biophilic Design, The Fat Plant Society, K.L. Riley, 2019

ABOUT TERRAPIN

Terrapin Bright Green is an environmental consulting and strategic planning firm committed to improving the human environment through high performance development, policy, and related research. Through conversation and collaboration, Terrapin helps break new ground in thinking creatively about environmental opportunities. Since 2006, Terrapin and its network of specialists have worked to shape the outcome of large-scale planning and design projects around the world. Terrapin has offices in New York City and Washington, DC, and works with private companies, public institutions, and government agencies on a variety of project types. Visit Terrapin and learn more at www.terrapinbrightgreen.com.

COPYRIGHT AND COMMERCIAL USE

This report is available to the general public without fee or other access control. Anyone may read this article or use it for their own personal or academic purposes. No commercial use of any kind is permitted without express written permission from Terrapin Bright Green except in the case of brief quotations (50 words maximum and for a maximum of two quotations per chapter) and with clear reference to the original source. The copyright of this article is by Terrapin Bright Green, LLC. The copyright of images is creative commons licence or by cited photographers.

SUGGESTED CITATION

Catherine O. Ryan, William D. Browning, & Dakota B. Walker (2023). *The Economics of Biophilia: Why designing with nature in mind makes financial sense*. Second edition. New York: Terrapin Bright Green, LLC. http://www.terrapinbg.com/report/eob-2

TERRAPIN
BRIGHT GREEN

© 2023 Terrapin Bright Green, LLC
Front cover figure: Royal College of Physicians, The Spine, Liverpool UK, courtesy AHR Architects Ltd.
Back cover figure: citizenM Times Square, New York City USA, courtesy Catherine O. Ryan

Contact: www.TerrapinBrightGreen.com | Biophilia@TerrapinBG.com | +1.646.460.8400

ACKNOWLEDGEMENTS

CO-AUTHORS

Catie Ryan	Terrapin Bright Green
Bill Browning	Terrapin Bright Green
Dakota Walker	Terrapin Bright Green

The authors would like to thank the many contributors for their valuable time and input.

CONTRIBUTORS

Alice Hartley, Gap Inc.
Carly Weber, OPN Architects
Erin Barnes, ioby
Gijs & Daan Bruggink, ORGA Architect
Jason Nelson, American Eagle Outfitters
Judith Heerwagen, University of Washington
Marc Coudert, City of Austin
Mirelle Phillips, Studio Elsewhere
Monica Olsen, Serenbe
Nancie Min, Clodagh Design
Randy Fiser, formerly of ASID
Robert Hopkins, AHR Architects Ltd.
Steve Nygren, Serenbe

EDITORIAL SUPPORT

Paula Melton	BuildingGreen

REVIEW COMMITTEE

Celine Larkin	Consulting Architect and Planner
David Kepron	NXTLVL Experience Design
Erin Jende	Interface
Ivan Sunde	Interface, Hospitality
Lucia Athens	City of Austin
Mardelle Shepley	Cornell University
Naomi Sachs	University of Maryland
Paula Meason	Interface, Healthcare & Education
Vivian Loftness	Carnegie Mellon University

edra
2014 Achievement Award

In addition, we would like to thank Rick Fedrizzi, Sally Augustin, Sue Weidemann, and Richard E. Wener. With their support, the first of edition of *The Economics of Biophilia*, released in 2012, was recognized with the Environmental Design Research Association's 2014 Achievement Award. We hope that this second edition builds on this legacy to support and inspire the environmental design community.

Interface®

SPONSORSHIP

This publication was made possible in part by support from Interface, a longtime champion of biophilic design, as evident in their products, work places, and publications.

DISCLAIMER

This report is based on the first edition publication (2012) and has been extensively revised and supplemented by research and analysis carried out between January 2020 and May 2023. The opinions, analyses and conclusions expressed in this report are solely those of the authors and do not necessarily reflect the views of the contributors, editors, reviewers, or supporting sponsor.

FOREWORD

"Home is where the heart is." It's something we've all seen stitched into a pillow or on a welcome mat, heard in a movie or from a loved one.

For three decades, my career has been kind of the reverse: my heart has been with homes… and offices…and schools…and hospitals. Really, my heart has been with buildings, first as co-founder and CEO of the U.S. Green Building Council, and now as executive chairman of the International WELL Building Institute. In that time, I've learned how essential the spaces where we spend our lives are to our health, and our well-being.

And yet, for thousands of years, as a species, our home was outside. It was among fields and trees and open air. Our schedules were ruled by sunlight, our skylines dominated by mountains, our ears filled with stillness or the sounds of running water.

So in a world of so many buildings, and ever-growing urban centers, how do we connect with where our biology is—where our hearts are?

That's where biophilic design comes in, and for individuals and institutions, it can be transformative. In fact, in my work on the WELL Building Standard, I've learned how improving the quality of the air can also improve the quality of someone's thinking and their work. How lighting informed by our natural circadian rhythms can lead to better sleep. How designing with nature (and human nature!) in mind isn't just good for the people inside the buildings—it's also good for business.

When I tell people this, their eyes go wide. And the next question is: how do you know? That's when I direct them to this report: *The Economics of Biophilia*.

With evidence and insight and years of expertise, Terrapin Bright Green makes the business case for biophilic design—loud and clear, and without question. This latest update of their seminal report only proves in greater detail something we all know intuitively: that if nature is part of human nature, then it should be an essential part of our buildings too.

So if you, like me, spend a lot of your time in buildings, or thinking about them, I hope you read this report and are inspired to make its principles a part of your work. We will all be better for it.

S. Richard Fedrizzi
Executive Chairman
International WELL Building Institute (IWBI)
August 23, 2023

NOTE FROM THE AUTHORS

At Terrapin, our consulting work focuses on creating, curating, and expanding public access to biophilia-related research, while also undertaking direct engagement in biophilic design projects. Our success—both as an environmental design consulting firm and in delivering on our mission to create a healthier world for all—is in part tied to the widespread access to, and adoption of biophilic design. **We believe in the power of nature to help create spaces and places that heal, nurture, and inspire.**

We are excited to issue a second edition of *The Economics of Biophilia*. Since the first edition's publication in 2012, we have received continuous positive feedback, expanded our knowledge with new research, and published several related studies and books. In this time, the first edition of *The Economics of Biophilia* has been recognized with the Environmental Design Research Association (EDRA)'s 2014 Achievement Award; the 14 Patterns of Biophilic Design (2014) has become a resource for designers, green building standards, and educators; and *Nature Inside, A Biophilic Design Guide* (RIBA Publishing, 2020) has allowed for a more contextualized exploration of the design process and storytelling.

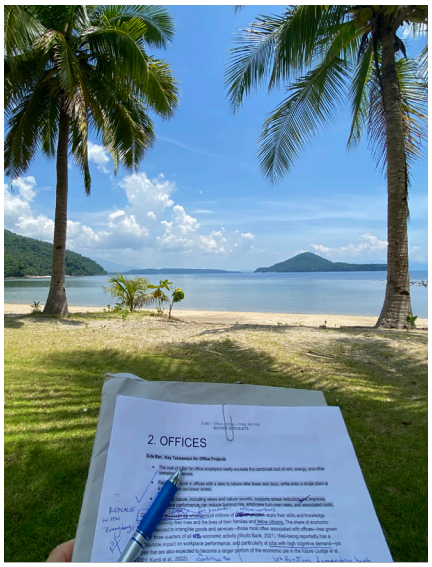


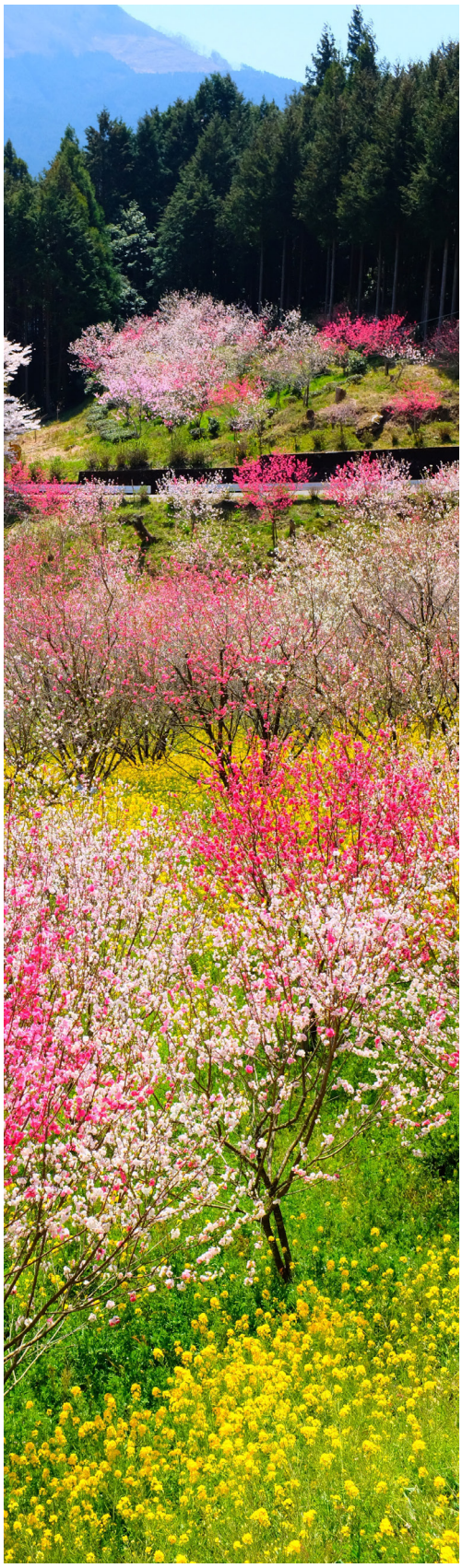
*FIGURE A. The final round of editing for this edition of "*The Economics of Biophilia*" was intentionally conducted in a multisensory, outdoor biophilic setting.*

The COVID-19 pandemic has shifted thinking, particularly among large corporations, from wellness to well-being—a more foundational framing for overall occupant experience. In addition, with new science and an evolving public, private, and institutional awareness—of workplace well-being, health equity, mental health, growing senior populations, urban flight, sustainability, governance, and other key societal issues—we recognized it was high time to circle back to the business case for biophilic design and planning.

This second edition of *The Economics of Biophilia* is a complete rewrite of the first edition. We have retained some indispensable financial extrapolations as well as commentary on particularly weighty studies from the first edition while introducing many new ones. This edition includes a new chapter on hospitality, and to each chapter we've also added case studies, practical do-it-yourself tips, and suggested areas for future research. The report draws on our experience supporting clients in developing biophilic design strategies and implementing them in the most cost-effective ways.

We are routinely assessing what is next for Terrapin. As we continue to raise awareness of the science of biophilia, we encourage others to help build a robust collection of business cases and tools to support the implementation and validation of biophilic design. We love participating in workshops and design projects, and writing guidelines for large scale developments in an effort to support communities, policy makers, and design practitioners. We look forward to collaborating with others to fulfill a shared vision for a healthy, biophilic built environment. We hope you will join us in this effort.

Catie, Bill & Dakota
Terrapin Bright Green
September 1, 2023



CONTENTS

FOREWORD BY RICK FEDRIZZI 3

NOTE FROM THE AUTHORS 4

EXECUTIVE SUMMARY 6

THE ECONOMICS OF BIOPHILIA

1. INTRODUCTION 8

2. OFFICES 17

3. EDUCATION 31

4. HEALTHCARE 43

5. RETAIL 58

6. HOSPITALITY 71

7. COMMUNITIES 84

GOING FORWARD 100

APPENDICES 101

A. RESEARCH OVERVIEWS 102

B. CALCULATIONS 105

C. REFERENCES 109

FIGURE B. Photo courtesy Unsplash

EXECUTIVE SUMMARY

With the emergence of a worldwide movement to improve health and well-being at all levels of society, many are looking to science and business cases that support the adoption of biophilic design as a means to improve the experience of the built environment. This publication argues in favor of biophilic design by examining scientific studies on the effects of nature-based experiences on human productivity, preferences, and attention in a variety of space types, and by assigning economic values to these outcomes as justification for investment. Sector-specific economic analyses are presented for the office, education, retail, hospitality, healthcare, and the community. The aim of this research summary is to show the economic value of offering biophilic experiences, not as a luxury, but as an investment opportunity with calculable returns.

For each sector there are direct and indirect indicators of economic success and of health impact. This report highlights research primarily on the neurological and biological effects of nature experiences, while introducing other benefits as they pertain to each specific sector (i.e., chapter), and expresses the outcomes of biophilic design in terms that are important to each sector and its respective key performance indicators (KPI).

Each chapter is structured with an introduction, research findings in biophilia, financial translations, a snapshot of contemporary industry practice, sample case studies, and suggested areas for future research. Appendices follow with an overview of research focus areas, supplemental calculations (where applicable), and a comprehensive bibliographic reference list.

OFFICES

Typical KPIs include absenteeism, presenteeism, recruitment, and retention. There is evidence that biophilic design also helps improve measures of workplace performance. While direct measures of productivity are rarely identical across the variety of workplace functions, transaction-based tasks give good insight into what is possible through design. For example, at a call center, better access to nature views can significantly improve call handling response rates.

EDUCATION

Learning rates and standardized test scores are common KPIs. There is evidence that biophilic design improves academic achievement and, among younger students, cognitive development rate. Academic performance is frequently an indicator of long-term economic success for the student, as well as for the school and the community.

HEALTHCARE

Surgical recovery times, patient bed turnover rates (BTR), average length of stay (ALoS), and analgesics intake are common KPIs, as are staff burnout risk and retention rates. There is evidence that biophilic elements can contribute to enabling more inpatient surgeries at a given facility. Evidence also indicates that biophilic elements can help mitigate occupational stress among hospital staff, which can indirectly help reduce burnout risk and contribute to staff retention.

> **"...Creating biophilic,** sustainable, and wellness-focused **spaces** isn't just **a sound investment.** It's doing **the right thing."**

BRIAN VICKERY
Senior Director, Design and Construction
Four Seasons Hotels and Resorts

in *Doing the Right Thing: Why Hotels Are Embracing Biophilic Design, The Fat Plant Society,* K.L. Riley, 2019. Emphasis added by authors.





FIGURES C–D. The concept for the new terminal at PDX International Airport in Portland, Oregon, intentionally employs biophilic design, including natural materials (C) and dynamic and diffuse light (C, D) to reduce passenger stress. The interdisciplinary effort resulted in a confluence of benefits, from supporting local tribal and family owned businesses, to carbon footprint reduction, seismic resilience, and occupant health and well-being. Photos courtesy Catherine O. Ryan

RETAIL

Dwell time, willingness to pay, and sales per square foot are common KPIs for retail. There is evidence that biophilic elements can increase shoppers' perceived willingness to pay, improve gaze attention, and increase dwell time—shopping behaviors that are known to contribute to additional sales. More street trees, for example, can increase willingness to pay, while an aquarium in a shop window can lead more customers to enter the store.

HOSPITALITY

The average daily room rate (ADR), revenue per available room (RevPAR), occupancy or booking rate, and total revenue per available room (TRevPAR) are common KPIs in hospitality. There is evidence that biophilic elements in guest rooms, such as a view to an exterior water body or vegetation or an interior vignette, can influence both willingness to pay and real room pricing—which can boost ADR and RevPAR. Evidence also supports that biophilic elements in hotel common areas and amenities can influence guest and visitor behavior, including increased number of active and passive users of a lobby and their likelihood of patronizing lobby cafés or bars—which can boost TRevPAR.

COMMUNITIES

Public health and safety, crime rates, and property values are conventional KPIs that are commonly accompanied by contemporary measures for tree canopy coverage and parks proximity. Evidence suggests that street trees and proximate green spaces can support better health outcomes, including willingness to walk, more prosocial behavior, and a reduction in crime. While proximity to parks and water bodies can increase property values, which is generally a good thing, equitable access to and distribution of green spaces is important to mitigate potential for displacement through gentrification.

Biophilic design has economic benefits that accrue across most sectors. Many strategies cost little or nothing to implement. This report provides a basis for carefully considering costs relative to benefits. While myriad variables influence investment choices and associated health benefits, research explored in this report captures a glimpse at how designing with nature in mind goes beyond good design, making financial sense with an enduring benefit to earnest adopters.

This report serves as a jumping off point for deeper conversation and research in support of both incremental improvements and new paradigms. In essence, the economic value of offering biophilic experiences is discussed, not as a luxury, but as an investment opportunity with calculable returns that support a local and global nature-positive economic agenda. ❖



1. INTRODUCTION

FIGURE 1.1. The savannas of Africa provided conditions to support humans; biophilic design brings those conditions into the built environment in ways that we are still biologically and psychologically receptive to. Photo courtesy Pixabay

The human experience is in large part dictated by our surrounding environment. Humans rely on the environment to help meet a hierarchy of needs, ranging from basic needs such as shelter and sunlight to nuanced physiological and psychological needs such as social interaction, a sense of security, mental restoration, biological homeostasis, visual acuity, and curiosity. When the built environment isn't adequately providing for such needs, the financial implications can be significant, though not always easily measurable. While there are many factors that influence decision making in the design and operation of spaces and places, and the value created is measured differently for each sector (healthcare, retail, education, etc.), policy makers, planners, and designers can look to biophilia to help make small improvements or even recalibrate our perceptions of and parameters for what constitutes a healthy built environment. This report is serves as a jumping off point for deeper conversation and research in support of both incremental improvements and new paradigms.

A growing awareness of the psychological and physiological responses associated with human contact with nature has been a source of inspiration for developing design strategies that improve the human experience of the built environment. Designing cities and buildings reflective of key sensory and spatial characteristics of nature has been shown to improve health, cognitive functioning, and emotional state. While such impacts for an

individual or group of people are significant in and of themselves, they also underscore "design" as a potential economic driver, capable of contributing to a more productive, happier, and healthier society. See "A Primer on Biophilia" at the end of this chapter for a more detailed introduction to the science behind biophilia, the researched health impacts, and how they relate to design.

While myriad variables influence a patient's recovery time, a customer's purchasing behaviors, or a student's learning rate, research explored in this report captures a glimpse of how designing with nature in mind goes beyond good design, making financial sense to boot. We believe that nature-based design will constitute an enduring benefit to the growing number of those who make the investment.

As rapid urbanization and technology dependence continually remove people from daily connections with nature, more than ever before do job responsibilities require higher-level cognitive skills and consumer demands prioritize bespoke retail, learning, travel and living experiences. With the 21st Century surge in mental health awareness, brain drain (at local and national levels), the rise of remote working, and a pandemic-era appreciation for having easy access to nature, it is timely for communities and institutions to look to biophilia as a means to heal (public health, equity rifts, climate impacts), attract and retain (residents, employees, tourists, businesses, investors, customers), and thrive (economic growth, stewardship, urban patriotism, gross domestic happiness, tax base).

By detailing the economic impacts of various science-backed biophilic health outcomes, this report aims to support project planners and designers with a basis for articulating the suitability of and rationale for biophilic design for a given project.

BIOPHILIA IN A NATURE-POSITIVE ECONOMIC AGENDA

As awareness of personal and public health grows and as nature-positive outcomes become more evident, nature loss has surfaced as a valid metric in risk analysis. According to the World Economic Forum (WEF), more than half of the world's gross domestic product (US $44 trillion of economic value generation) is dependent upon Mother Nature (WEF, 2020).

The WEF's Nature Action Agenda engages multiple sectors of society for "catalyzing economic action to halt biodiversity loss by 2030 and enable humans to live in harmony with nature." The 2020 publication "Nature Risk Rising" (WEF, 2020), produced by WEF in collaboration with PwC, identifies three categories of hidden risks of nature loss for businesses:

1. Risks emerging from dependency of business on nature,
2. Risks from fallout of business impacts on nature, and
3. Risks from impacts of nature loss on society.

Planning and design efforts have much to consider if they are to repair this nature loss on society. By factoring humankind's innate connection with nature into practices and policies for sustainable building and regenerative land management—including urban green infrastructure, agriculture, and regional ecologies—communities and organizations are working toward mitigating nature-related risks to society and the economy. Communities building back their natural capital are able to create value that includes, among other things, individual and public health benefits. With nature-positive economic measures in place, broader and more profound impacts on society can be had with biophilic design strategies that target each sector and user group. A nature-positive approach can benefit the resilience of communities, their people, and their businesses—on a daily basis and in the face of economic disruptions, health disparities, and climate change. (See Africa et al., 2019, for more on the links between biophilic design and climate change.)

This publication argues in favor of biophilic design by examining scientific studies on the effects of nature-based experiences on human health and well-being—in terms of performance and productivity, preferences, and behaviors (see "Primer on Biophilia" for more depth)—in a variety of space types, and by assigning values to these outcomes as rationale for prioritization in design and investment. High level economic analyses are presented for offices, schools, retail, hospitality, healthcare, and communities. The aim of this research summary is to show the economic value of offering biophilic experiences, not as a luxury, but as an investment opportunity with calculable returns at the project level that support a local and global nature-positive economic agenda from multiple angles:

- A healthier and more productive workforce that contributes to a stronger and more resilient local economy;
- Healthcare servicescapes that are more economically viable and embraced by the community;
- Retail centers that help entice more residents to spend more money within the community boundary;
- Hotels that attract travelers and bolster local tourism and brand loyalty;
- School learning environments that help sustain and expand human capital and innovation within the community; and
- Community environments that enable equitable access to experiences of nature to help enrich public health, biodiversity, and adapt to a changing climate.

Each chapter of this report expounds upon the benefits of biophilic design in offices, retail venues, hospitality, healthcare facilities, educational spaces, and communities.

PERFORMANCE INDICATORS IN HEALTH & FINANCE

The physiological and psychological results of exposure to nature can often be expressed in terms of direct or indirect economic value. Direct measures of economic value encompass quantifiable changes in behavior that can be assigned monetary values and converted to cost savings or increased revenue. For example, increasing the number of customers served, hotel rooms booked, or calls taken during a given time period directly contributes to higher revenue.

DIRECT & INDIRECT BENEFITS

Indirect measures are those that must be translated into a dollar value by approximating their impact on a corresponding economic value metric. For example, the value of a park can be estimated by finding the average hypothetical price someone would be willing to pay to keep it from being developed. Though often a complex calculation, indirect costs and benefits can significantly influence the bottom line. This report explores direct and indirect economic valuation metrics and indicators, which have been translated into dollars where applicable. Table 1 gives an overview of key performance indicators (KPI) relative to sectors covered in this report.

When linked to the effects of a renewed connection with nature, these indicators reveal remarkable potential for financial gains. However, the economic benefits of investing in occupant/user health and well-being are often overlooked because of the difficulty of quantifying variables associated with the positive outcomes. User health and well-being are rarely part of the conventional cost/value engineering model for building and development projects that have an express emphasis on initial investment cost. With the growing interest in and adoption of environmental, social, and governance (ESG) metrics and impact investing (investments with broader purpose beyond profits alone), investment parameters and value engineering will hopefully soon incorporate post-construction impacts on occupant/user health and well-being, along with other fundamental factors supporting a resilient and healthy society.

TABLE 1. BIOPHILIA IMPACTS FOR POSITIVE RETURNS

INDICATOR	HEALTH & WELL-BEING IMPACTS	FINANCIAL IMPACTS	
SECTOR		DIRECT	INDIRECT
OFFICES	presenteeism, performance, productivity	absenteeism, staff retention; lease rate, churn	talent acquisition, health claims, employee satisfaction
EDUCATION	attention, learning rate	absenteeism, test scores	graduation rates
RETAIL	customer attention, brand perception	hedonic value, sales; staff retention	dwell time, return patronage, social media attention
HEALTHCARE	healing rate, analgesic intake	patient turnover; staff retention	visitor perception
HOSPITALITY	staff performance, perception of place	average daily room rate (ADR, RevPAR)	employee satisfaction, brand loyalty, social media attention; total revenue per available room (TRevPAR)
COMMUNITIES	perception of safety, crime rate; overall public health	tourism; crime rate	investment attraction, migration; real estate value, tax base; climate change adaptability, resilience, equity; incarceration rate



FIGURE 1.2. The Spine is home to the Royal College of Physicians in Liverpool UK. Wood treatments, vegetation, biomorphic carpet patterning, and dappled lighting, as well as perceptions of prospect and refuge, was the result of a collaboration between tenant owner, architect and others explicitly aimed at incorporating neuroscience of biophilia to create a healthy place to work, study, and teach. Photo courtesy AHR Architects Ltd.

CALCULATING BENEFITS

Biophilic design can be overlooked for the same reason that green or sustainable design was in its early adoption years—such as perceived higher first costs and lack of data sharing—despite having meaningful returns on investment. As a result, conventional practices has systematically focused investment on easily quantifiable benefits (e.g., faster computers; LED lighting systems) and under-investment in solutions with benefits that cannot easily be quantified (e.g., operable windows; acoustic waterwalls). By clarifying the economic opportunities that biophilic design presents, decision-makers can more effectively allocate investment toward solutions with optimal returns that sustain over time.

There are countless examples of biophilic design implemented at offices, schools, hospitals, hotels, food and beverage venues, and at civic and community parks and facilities. Few, however, analyze or publicize the economic implications of those efforts. At the time of writing this report, such case studies have been included where evidence and data was available. Elsewhere, gaps in research and applied examples have been called out.

The calculations in this report are not intended to pinpoint an exact numeric cost benefit for a sector or project, but rather to contextualize opportunities for biophilic design and relative scale of economic impact. The following arguments also focus primarily on big-picture economic benefits, rather than the upfront costs associated with particular biophilic design interventions. This approach is in part due to investment cost having many of its own variables and is not often explicitly factored into scientific literature on biophilia. It is the authors' hope that readers may take the economic benefits summarized in this report and analyze them according to their own pricing models to determine the net benefit of biophilic design in a given context.

A PRIMER ON BIOPHILIA

Humans have evolved in the larger context of the natural environment and in response to our natural surroundings. Our ancestors, having remained hunter-gatherers until fairly recently in human history, were actively engaged with nature and occupied dwellings that were dependent upon and integrated with their natural surroundings. As a result, our development has been entrained by sensory interactions with nature and a familiarity with the spatial properties of natural landscapes. In the age of the Industrial Revolution (1760–1840), a transformative shift toward urbanization, fabrication, and isolation from nature ushered in a departure from active interactions with the natural world. Over time, the workforce became more familiar with the conveyor belt and the cubicle than with the versatility and cycles of the natural world.

The term biophilia, stemming from the Greek roots meaning 'love of life', was coined in the 1950s by German social psychologist Erich Fromm. It came into use in the 1980s when American biologist Edward O. Wilson realized the implications of this departure from nature. He subsequently pioneered a new school of thought focused on the need to bring humans back in contact with nature. "Biophilia," Wilson described, "is the innately emotional affiliation of human beings to other living organisms." He added, "Life around us exceeds in complexity and beauty anything else humanity is ever likely to encounter" (Wilson, 1984).

The Biophilia Hypothesis, introduced in the 1993 publication with the eponymous title, by Wilson and American social ecologist Stephen R. Kellert, posits that humans possess an innate tendency to seek connections with nature and other forms of life. This concept of biophilia implies that humans hold a biological need for connections with nature on physical, mental, and social levels, and that these connections affect our personal well-being, individual performance, and societal resilience. Whether one is engaging with nature by walking through a park, interacting with animals, or viewing greenery from a window, the presence of biophilia helps transform mundane settings into stimulating and salutogenic (health positive) environments.

OVERVIEW OF THE SCIENCE

The benefits of biophilia are vast and are often framed either in terms of health domains (e.g., sleep patterns, digestion, memory), neurological or biological effects (e.g., stress, mood, preference, creativity, cognitive performance), or social effects (e.g., public health, hedonic value, prosocial behavior, stewardship, equity). This report highlights research primarily on the neurological and biological effects, while introducing these other benefits as they pertain to each specific sector (i.e., chapter).

Although the concept of biophilia is relatively straightforward to grasp, its neurological and physiological underpinnings are the key to understanding its value. Millions of neural channels in our brain are linked to the human body's autonomic nervous system. This system consists of two elements: the sympathetic and the parasympathetic systems. The sympathetic system stimulates the human body when cognitive function is needed. The parasympathetic system serves to relax the body, and is used for internal processes such as heart rate and digestion. When the body's natural balance of sympathetic and parasympathetic is achieved, the body is in the ideal state of homeostasis. Human interaction with nature provides an increase



FIGURE 1.3. Paintings of the Hudson River School, such as this one by American painter Robert Havell, Jr. (1793–1878), were highly biophilic, frequently depicting a distant view, refuge, vegetation, water, and evidence of human habitation—key components supporting the Savanna Hypothesis (Heerwagen and Orians, in Kellert & Wilson, 1993).

in parasympathetic activity signifying better bodily function, decreased stress, and increased ability to concentrate (Brown, Barton & Gladwell, 2013).

Getting a sense of the range of impacts to physiological well-being, cognitive performance, concentration, mood and preference can give us important clues as to how we can harness the power of biophilia. Here are a few foundational concepts and theories that support biophilic design research and practice.

PHYSIOLOGICAL EFFECT

Physiological factors are those pertaining to an individual's bodily functions as well as to the chemical and physical processes involved in the body's functioning. While not all research projects use the same parameters for assessing physiological impacts of a stimulus or experience, there are a variety of representative tools and measurements that are common among studies discussed in this report:

- **Heart Rate** tracks pulse rate as an indicator of stress.
- **Heart Rate Variability** tracks variability of heart rate as an indicator of stress recovery.
- **Cortisol Level** measures the level of cortisol hormone in an individual's blood, urine, or saliva as an indicator of the body's ability to respond to stress.
- **Skin Conductance** measures the electrical conductivity of the skin (usually of the fingers or hand) as an indicator of psychological or physiological stress.
- **Eye Tracking** measures an individual's eye position and movement, following what they are looking at in real-time, as an indicator of interest, attention or focus, aesthetic appeal, or emotional response to an environment or stimulus, as well as levels of confusion, drowsiness, or navigability.

The outcomes from these measurements give insight to a test subject's physiological well-being. Within the range of biophilic design related research, physiological outcomes are shown to be consistent with **Stress Recovery Theory** (SRT).

SRT is a psycho-evolutionary theory that posits that natural environments buffer against and facilitate better recovery from stressors (Ulrich, 1983). For instance, forest bathing, or Shinrin-yoku in Japanese, is a research subject that has provided solid evidence for SRT and further highlights the positive physiological impacts of nature exposure. The effects of walking through forest atmospheres versus urban areas have been documented by comparing the salivary cortisol, blood pressure, and heart rate of subjects (e.g., Park et al., 2010).

COGNITIVE FUNCTION & CONCENTRATION

According to the *APA Dictionary of Psychology*, **cognitive functioning** is "the performance of the mental processes of perception, learning, memory, understanding, awareness, reasoning, judgment, intuition, and language", whereas **cognitive development** is "the growth and maturation" of those thinking processes. In biophilic design research, cognitive development studies tend to focus primarily on early childhood education settings; whereas, cognitive functioning is often a performance indicator in studies of adult populations, particularly within office and healthcare environments.

While not all research projects use the exact same parameters for assessing cognitive performance, there are a handful of representative neurobehavioral and neuropsychological tasks that are common among many studies (e.g., Yin et al., 2018; Shen, Zhang & Lian, 2020):

- **Meaningless Picture Recognition** tests long-term memory.
- **Visual Choice Reaction Time** tests reaction time to change of visual stimulus.
- **Visual Backward Digit Span** tests short-term memory and info manipulation.
- **Continuous Operation** measures sustained and selective attention.
- **Number Calculation** assesses the speed and accuracy.
- **Stroop** tests ability to inhibit cognitive interference that occurs when processing of a specific stimulus attribute impedes the processing of another (e.g., identifying the color of this word: blue).

The outcomes from these tasks give insight to a test subject's thinking processes and expressive functions. Within the range of biophilic design related research, cognitive performance outcomes are shown to be consistent with **Attention Restoration Theory** (ART).

ART holds that nature provides a positive restorative environment for human mental capacities, reducing the impacts of distraction and allowing concentration to be sustained for longer durations (Kaplan, 1995). In order to focus, whether crossing the street or solving a complex analytical problem, the brain must employ a neurological restraint that limits distraction or stimulation by other tasks or stimuli—a function that requires a great deal of energy. Attention fatigue results when environments overburden this restraint mechanism and its capacity becomes temporarily depleted. Attention fatigue slows the heart rate and breathing while simultaneously arousing digestion to raise energy levels; this combination lowers concentration and decreases effectiveness (Maas, 2011). When viewing nature, the brain quiets down, and we operate in a state of "soft fascination" (when attention is held by a less active or stimulating activity). After this experience, cognitive and attentional focus is restored. As little as 40 seconds can restore attention control and improve task performance (e.g., Lee et al., 2015).

MOOD & PREFERENCE

Mood denotes any short-lived emotional state, usually of low intensity (e.g., cheerful mood, irritable mood); there are believed to be over two dozen human emotions (Cowen & Keltner, 2017). **Preference** is the act of choosing one option over others (e.g., view preference, seating preference). The moods and preferences of an individual can each be influenced by exposure to biophilic experiences.

Views of complex, dynamic natural scenes are known to trigger many more interactions of the *mu* (opioid) receptors in the large rear portion of the visual cortex. Viewing nature is literally a pleasurable experience. Views with less visual richness, such as a blank wall or a tree-less street trigger far fewer mu receptors, resulting in fewer pleasurable mental reactions (Biederman & Vessel, 2006). Work by a team at Stanford University found that a walk in nature versus in an urban setting can lead to lower rates of rumination, which can help reduce risk of depression (Bratman et al., 2015). Some experiences of nature, such as the feeling of awe, can also result in improved prosocial behavior (Piff et al., 2018).



FIGURE 1.4. Prolific architect Frank Lloyd Wright is known for his creation of homes that reflect his mood, with distinct experiences of prospect, refuge, risk, vegetation, and water. Photo courtesy Bill Browning

These scientific studies provide some clarity regarding the fundamental health benefits of biophilia. While the direct and indirect costs of nature deprivation haven't been thoroughly researched, consideration for this type of research when developing an approach to built environment projects is rapidly expanding as owners and designers increasingly value the practice of design informed by science. Growing emphasis on building performance and human cognition studies have prioritized initiatives that employ and study biophilic design. Biophilia-based planning and design are reflective of the relationships between health, economics, and the natural environment.

BIOPHILIA-BASED DESIGN

Biophilic design can be intuitive or intentional. When intentional, it uses science to target desired experiences and responses to the built environment. Three pillar concepts serve as categories for the patterns of biophilic design: Nature in the Space, Natural Analogues, and Nature of the Space.

NATURE IN THE SPACE

Direct experiences of nature in the built environment are patterns of Nature in the Space. Examples include potted plants, water features, aquariums, and courtyard gardens, as well as views to nature from the inside of a building. The prevalence of the courtyard in traditional architecture is a good example of our early attraction to intentionally incorporating nature directly into our built environment. These direct connections with nature, especially dynamic nature, can produce strong positive responses.

NATURAL ANALOGUES

A degree of separation away from true nature, Natural Analogues are materials and representative patterns that evoke nature. These analogues can be characterized as either representation, ornamentation, biomorphic forms, or natural materials. Examples of natural analogues include textiles that feature shells and leaves, furniture with organic rather than geometric shapes, fractal patterns like the dappled light under trees, and paneling with visible wood grain. Available research indicates that the benefits of natural analogues are measurable but maybe less impactful than benefits derived from dynamic, living nature.

NATURE OF THE SPACE

Spatial configurations prevalent in nature are patterns of Nature of the Space. Humankind, having developed amongst low-growing grasses, clusters of shade trees, and broad vistas, has a modern-day affinity for similar landscapes in indoor and outdoor environments (Heerwagen & Orians, in Kellert, Heerwagen & Mador, 2008). The design concepts of prospect and refuge—elevated views coupled with protected spaces—as well as mystery, risk, and awe—exploring unseen space and evoking pleasurable distress—are examples of Nature of the Space. Each of these five experiences or perceptions (i.e., prospect, refuge, mystery, risk, awe) activate distinctly different portions of the brain (Chatterjee, 2023). Common architectural examples include nooks, covered porches, and window orientation toward open views, distant light sources, curving hallways, or cantilevering patios.

These three categories and similar frameworks are explored in greater depth in *14 Patterns of Biophilic Design* (Browning, Ryan, & Clancy, 2014), *Nature Inside, A Biophilic Design Guide* (Browning & Ryan, 2020), and the "Biophilic Design Toolkit" hosted by the International Living Future Institute (see ILFI, 2022).



FIGURE 1.5. Natural materials and prospect views have become essential biophilic experiences for workplace design intended to have a meaningful positive impact on employee stress and workplace perception. Photo courtesy shawnanggg on Unsplash



2. OFFICES

Everyday tens of millions of office workers apply their skills and knowledge toward improving their lives and the lives of their families and fellow citizens. The share of economic activity devoted to intangible goods and services—those most often associated with offices—has grown to over three quarters of all economic activity in the U.S. alone (World Bank, 2021). Well-being reportedly has a measurable impact on workplace performance, and particularly at jobs demanding high cognitive performance—job functions that are also expected to continue becoming a larger portion of the economic pie in the future (Judge et al., 2001; Kundi et al., 2022).

In an ideal work environment, employees would be happy, engaged, healthy, and free of unnecessary stressors. An investment in biophilic design in offices may aim to show quantifiable returns in lower absenteeism, improved task performance, and greater job satisfaction amongst employees. Given the demands of twenty-first century office work, well-being among office workers is almost never optimal. Burnout,

KEY TAKEAWAYS

- People who work in offices with a view to nature take fewer sick days.
- Access to nature views, vegetation, daylight and nature sounds supports stress reduction, improves workplace performance, and reduces burnout risk, employee turn-over rates, and associated costs.
- Offices with easy view access can increase productivity to a point that exceeds the combined cost of rent, energy, and other operating expenses.

FIGURE 2.1. Prospect, refuge, dynamic light, and vegetation at Copernico Blend Tower, Piazza Quattro Novembre in Milan, Italy. Photo courtesy Copernico on Unsplash

TABLE 1.2. BIOPHILIA IMPACTS & FINANCIAL INDICATORS FOR OFFICES

SECTOR	HEALTH & WELL-BEING INDICATORS	FINANCIAL INDICATORS	
		DIRECT	INDIRECT
Offices	performance, productivity, presenteeism	absenteeism, staff retention; lease rate, churn	talent acquisition, employee satisfaction, health claims

now a globally recognized health issue (World Health Organization, 2019), is said to affect 76% of the U.S. workforce at least sometimes, with 28% experiencing burnout more often than not (Gallup, 2020). Chronic, unmanaged workplace stress results in missed workdays, lower rates of productivity, and more voluntary employee turnover (Gallup, 2020). Given that employee costs account for a majority of total office operation costs on a per-square-foot basis—typically more than 90% in the U.S. (see Appendix B1)—supporting employee health and well-being can have a significant impact on an employer's bottom line.

While many companies have invested in wellness programming or have revised workplace culture to enable better work-life balance, the building design itself has been shown to be a significant influence on employee health and well-being. Among office characteristics found to most strongly correlate with health, productivity, and the overall comfort of office workers, having a connection with (actual or representational) nature is reportedly among the top seven characteristics, the other six of which are: spatial comfort, indoor air quality, building image and maintenance, noise distraction and privacy, visual comfort, and personal control (Candido et al., 2019). In 180 post occupancy surveys, Candido and colleagues also identified that the highest-performing offices had particular design attributes in common—each of which are patterns of biophilic design:

- Spaces with organic shapes and patterns,
- Spatial configurations and seating with prospect and refuge conditions, and
- Direct access to views and indoor greenery (Candido et al., 2019).

This chapter looks at available research on these patterns of biophilic design as they relate to stress reduction and reduced sick days (absentee rate); cognitive functioning and job performance; and mood, preference and job satisfaction across a variety of financial indicators for offices (Table 1.2).

STRESS REDUCTION & ABSENTEEISM

A rudimentary assessment of a worker's economic contribution is through the amount of time they spend working. Employee time lost is a function of two variables: time spent in the office and time spent actually working when in the office. Absenteeism—which speaks to the first variable—refers to the time employees are absent from work due to illness, injury, or other personal reasons. In the U.S., the average absenteeism rate in the



Figure 2.2. In Old Town, Portland, Oregon, cultural and ecological heritage is represented through a local artist's representations of nature on each floor at PAE's office in the World's first developer-driven Living Building. Photo courtesy Bill Browning

private sector is 1.2% or 25 hours per employee per year (Bureau of Labor Statistics, 2020).

The second variable, presenteeism, accounts for the phenomenon in which employees clock in for work but are mentally or physically unable to be productive, whether due to sleepiness, headaches, environmental distractions, ergonomic discomfort, or other physiological and psychological stressors. It is conservatively estimated that employees on average spend 9.04 days (72.32 hours) per year at work in a state of low or sub-optimal work performance due to health issues (Mitchell & Bates, 2011). Assuming employees are 50% less productive (Chimed-ochir et al., 2019) during those 72 hours of the year, the average employee loses 36 hours of work time each year or 1.7% of their total yearly work time. Combining absenteeism and presenteeism, nearly 3% of total productive work time is lost due to physical ailments and resulting mental distraction (Figure 1). Given industry averages, employee absences and suboptimal workplace productivity amount to an estimated $2,806 in unproductive salary costs per employee per year (see Appendix B2).

For office workers on a fixed salary, lost work time is essentially an unproductive expense for the employer. The average revenue per employee among professional service businesses in the U.S. was estimated to be $571,932 per year, or $274.97 per hour (CSI Market, 2020). As such, the cost of lost revenue from absences or unproductive time at work is estimated to be $17,158 per employee per year, or $3,431,592 for an office of 200 employees (see Appendix B2).

Among the primary causes of worker health issues, stress and anxiety have been shown to significantly correlate with increased absenteeism and presenteeism. As an example, in a 2017 study workers self-reported their anxiety level on a 21-point scale; every additional one-point in the ratings correlated to an 8.4% increase in sick days taken (Schneider et al., 2017). The American Institute for Stress found that every day one million workers across the U.S. are absent from work due to stress, resulting in a loss to U.S. companies of $300 billion per year (American Institute for Stress, n.d.).

BIOPHILIA RESEARCH FINDINGS

Biophilic design has been shown to significantly reduce overall stress and improve the ability of individuals to manage their stress recovery. Most research related to stress recovery in offices has focused on nature soundscapes and views.

SOUNDSCAPE

Office noise, especially prevalent within open-plan offices, is reportedly the factor that is most disruptive to indoor environmental quality and has been shown to increase stress and presenteeism (Haapakangas et al., 2008; Evans & Johnson, 2000). While noise disturbance has conventionally and effectively been addressed with sound masking (e.g., pink noise or white noise generation), research suggests that nature sounds (e.g., flowing



FIGURE 2.3. Many office furniture manufacturers have been investing in product designs that enhance the biophilic workplace experience. OFS's "LeanTo", a modular, booth-style seating concept, intentionally uses Natural Analogues (wood finishes) and Nature of the Space (refuge) to emphasize being a place to escape and regain cognitive capacities and attention. Photo courtesy OFS.



FIGURE 2.4. Biomorphic fractal-like façade gives iconic status to the Sumatrakontor mixed-use office building in Überseequartier, HafenCity, Hamburg, Germany. Design by Erick van Egeraat and Michiel Raaphorst (2011). Photo by Michoff on Pixabay

water, bird song) have superior performance in combating stress from noise disturbance (Browning & Walker, 2018; Alvarrson et al., 2010; Annerstedt et al., 2013). Using skin conductance sensors to test stress levels, Alvarrson and colleagues (2010) found that a combination of sounds from a bird and a fountain facilitated up to a 37% faster stress recovery time from noise disturbance—thus reducing presenteeism—than from the alternative non-nature sounds.

VIEWSCAPE

One of the earliest studies on improved stress recovery from a visual biophilic experience was conducted by Roger Ulrich and his colleagues in 1991, when videos of nature (in comparison with urban views) were shown to improve the speed and degree of stress recovery across four physiological measures: heart period, muscle tension, galvanic skin conductance, and blood pressure (Ulrich et al., 1991).

A direct connection between biophilic design and the economic impacts of absenteeism was highlighted in a 2011 study of an administrative office building at the University of Oregon (Elzeyadi, 2011). Researchers assessed a workplace where 30% of the workstations overlooked trees and a manicured landscape to the north and west; 31% overlooked a street, building, and parking lot to the south and east; and 39% were on the interior of the building, offering no outside view. Employees with the view of trees and landscape (north and west) took 16% fewer hours of sick leave (an average of 11 fewer hours) per year compared with those taken by employees with no view. The study found the quality of an employee's view to be the primary predictor of absenteeism.

Research continues to reconfirm positive responses, such view satisfaction and job satisfaction, related to employees having outdoor views (Lottrup, Jensen, & Stigsdotter, 2015). Research also shows that even minor interior biophilic design interventions can reduce measured and self-reported stress and anxiety (Toyoda et al., 2020; Yin et al., 2018; Yin et al., 2019). For example, during periods of fatigue participants looking at a plant, as opposed to a blank desktop monitor, experienced significant reductions in standardized stress test scores and, among 27% of the participants, significant reduction in pulse rate (Toyoda et al., 2020). Looking more holistically at a range of interior biophilic design patterns, another study found participants in a "biophilic" room had significantly lower systolic blood pressure and lower galvanic skin conductance—both indicative of lowered stress—than those in a non-biophilic control room (Yin, 2018).

FINANCIAL TRANSLATION

Effective daylighting, ample views to nature, interior greenery, and natural soundscapes have each been shown to resolve some of the underlying conditions that distract and fatigue workers resulting in high rates of absenteeism and presenteeism. For example, leaning on the University of Oregon study, the recapturing of 11 hours (or 16%) of working time per employee per year, when applied to a 200-person office, using average

WORKPLACE PERFORMANCE VARIABLES

Workplace performance often varies depending on factors such as occupational stressors (management style, deadlines, level of control over work process), environmental distractions (background noise, active interruptions), space design (visual, thermal, ergonomic comfort), mental fatigue, and personal health profile (commuting pressures, financial strains, family illness, bereavement). Some stressors and distractions can be tempered by other variables, most befittingly biophilic design of spaces, places, and experiences.

workplace financial assumptions, yields an increase in company revenue of $605,000 per year—nearly all of which would translate directly into profit after accounting for the investment for related design interventions (see Appendix B3).

COGNITIVE FUNCTIONING & JOB PERFORMANCE

In many industries, one of the most direct measures of employee contribution is their overall effectiveness at tasks, often referred to as workplace performance. Workplace performance includes employee productivity which is a quantifiable measure of the amount of output produced per unit of time (e.g., per hour) with the lowest level of errors and corrections required. Two employees may differ significantly in how fast and how well they can complete the range of tasks assigned, but for each employee, their task productivity, as well as their overall workplace performance can waiver depending on a number of variables (see side bar "Workplace Performance Variables").

BIOPHILIA RESEARCH FINDINGS

Research shows that experiences of nature views, natural materials, and nature sounds are able to restore attention, improve cognitive performance, and reduce mental fatigue. (See "Primer on Biophilia" in the Introduction chapter for an overview of measures of cognitive performance.)

NATURE VIEWS, NATURAL MATERIALS AND PRODUCTIVITY RATES

Pioneering research conducted in 2003 by Lisa Heschong of Heschong Mahone Group quantified the improved cognitive performance associated with views to nature. In Heschong's study, workstation locations and access to seated views at the Sacramento Municipal Utility District Call Center revealed notably varied worker performance results. The number of calls handled per hour increased by 6%–7% for the employees with greater seated access to window views of landscape as compared to those handled by employees with no view of the outdoors; moreover, office workers with the best views were found to perform 8%–16% better on tests of cognitive function than workers with no view (Heschong, 2003).

Other research continues to reinforce Heschong's early study; indoor connections with nature, specifically with vegetation and natural materials, have shown to positively impact workplace performance for a variety of indicators.

In illustration, workplaces with indoor vegetation:

- Reduction in measured stress (Toyoda et al., 2020)
- Higher concentration (Nieuwenhuis et al., 2014)
- Improvement in productivity (Nieuwenhuis et al., 2014)



FIGURE 2.5. Food manufacturer Clif Bar intentionally focused on creating biophilic amenity spaces to better help employees relax and restore when taking breaks from the production floors where sterile environments are necessary due to food health safety requirements. Photo courtesy Clif Bar

- 10% Improvement in measured task performance (CBRE, 2017)

Workplaces with natural wood finishes:

- Increase in user-perceived productivity (Shen, Zhang & Lian, 2020)
- 10% Improvement in overall speed and accuracy (Shen, Zhang & Lian, 2020)

Workplaces with indoor vegetation and natural wood finishes:

- 6% increase in user-perceived productivity (Interface, 2015)
- 15% increase in creativity (Interface, 2015)

NATURE SOUNDS, ERROR RATES AND CREATIVITY

Noise distraction in the workplace contributes to an estimated drop of 4%–41% in cognitive performance (Hongisto, Haapakangas & Haka, 2008; Hongisto, 2005). Biophilic auditory interventions—as an alternative to conventional masking practices—in the office have been shown to improve worker performance. Testing by Van hedger and colleagues (2019) recorded an average 13.9% improvement in cognitive performance after introducing nature sounds as opposed to an urban soundscape (see Appendix B4). In an office laboratory, Haapakangas and colleagues identified that white noise, pink noise, and instrumental and vocal music caused an increase in error rate over that in a silent space. The research also assessed cognitive performance under various masking noises over speech—spring water, instrumental and vocal music, white noise, and pink noise—revealing that when compared to working in silence, a significant increase in error rate can be detected for all masking sounds except water, for which a significant decrease in error rate and increase in creativity have been reported (Haapakangas et al., 2011).

FINANCIAL TRANSLATION

Improvements in worker productivity and performance can be quantified to illustrate the economic implications of biophilic design that supports stress reduction, attention restoration, and improved cognitive function. Referencing to the Heschong study (2003), enabling direct visual access to nature from a seated position boosted call center productivity by 6%, amounting to a benefit of $2,990 per employee. Factoring in the cost ($1,000 per workstation) of the improvements (each one canted 11 degrees), the project saw a 299% return on investment—a payback of four months.

The range of studies linking productivity (cognitive tests, self-reporting, work tasks completed, etc.) to biophilic design interventions (natural materials, indoor plants, views to nature, and natural soundscapes) reveal a 6%–15% improvement in productivity, with an average of 11% (Heschong, 2003; Interface, 2015; CBRE, 2017; Lohr et al., 1996; Nieuwenhuis et al., 2014; Shen et al., 2020; Van Hedger et al., 2019; Yin et al., 2018). Given average workplace financial assumptions, an 11% improvement to worker productivity, would bring in an additional $36,471 per employee per year. Across an office of 200 workers, this would increase annual revenue by an estimated $7.29 million (see Appendix B5).

MOOD, PREFERENCE & JOB SATISFACTION

Job satisfaction, while often overlooked, has a clear and direct impact on company expenditures and overall profitability. Not only do happy employees tend to have fewer sick days and higher levels of productivity, but they also tend to stay with the organization for longer (Harter et al., 2003). In 2019, approximately 27% of all U.S. workers voluntarily quit their job (Work Institute, 2020). Often referred to as voluntary job separation or turnover, the rate is even higher in the professional and business services industry, with a 2019 voluntary turnover rate of 36.5% (BLS, 2021). After “Career” and “Retirement”, “Workplace Environment” and “Health & Family” were identified as the only two other reasons for voluntary departure from places of employment to have increased in 2021 compared to pre-COVID-19 rates (See Figure 2; Work Institute, 2021). Moreover, the voluntary turnover rate is increasing—up 88% since 2010—and the trend is expected to continue (Work Institute, 2020).

When factoring in recruitment costs, training, and lost productivity, replacing an employee is estimated to cost between 30% and 60% of the employee’s salary (Work Institute, 2020; Allen, 2008). Retention is, in large part, a function of job satisfaction and well-being. One in ten employees who quit do so for reasons related to well-being (Work Institute, 2020) and research by Sears and colleagues (2013) found well-being to be a significant predictor of job performance, healthcare costs, and employee turnover. Sears’ research also found that employees in the top ranking of

well-being had a 30% lower voluntary turnover rate overall and a 300% lower rate than those in the lowest ranking of well-being (Sears et al., 2013).

Research shows that nature sounds and indoor vegetation support mood, preference and job satisfaction, including overall happiness on the job. See "A Primer on Biophilia" in the Introduction chapter for an overview of measures of mood and preference.

BIOPHILIA RESEARCH FINDINGS

SOUNDSCAPE

Office noise can significantly affect job satisfaction, mood, and well-being (e.g., Park et al., 2020). Natural soundscapes as noise masking have been shown to outrank conventional masking sounds in pleasantness (Alvarrson et al., 2010), improve environmental satisfaction (Haapakangas et al., 2011), and enhance mood recovery (Benfield et al., 2014). The perceived restorative effects of experiencing nature sounds are also heightened with the presence of a corresponding visual component such as a view or video (Pheasant et al., 2010; Jahncke et al., 2011). Research by Jahncke and colleagues (2011), for instance, revealed that participants experiencing video and audio of a river (simultaneously) in the office rated themselves as having more energy and motivation as compared to those who were exposed to typical office sounds (Jahncke et al., 2011).

INDOOR VEGETATION AND NATURAL MATERIALS

In a global survey of 7,600 employees in 16 countries, the Human Spaces 2.0 report (Interface, 2015) identified both a significant demand for biophilic design and significant improvements in psychological well-being for those in biophilic offices. Among offices with internal greenery, 6% more respondents recorded being happy and 14% recorded being more inspired, with 3% fewer respondents feeling anxious and 6% feeling bored; overall, well-being increased by up to 15% for those in offices surrounded by natural elements as opposed to those who had no contact with nature in the office (Interface, 2015). These findings are consistent with the CBRE survey reporting a 76% increase in perceived energy levels and 78% increase in happiness for employees with indoor plants, when compared to the baseline office condition without plants (CBRE, 2017).

Several other studies have directly explored the positive impacts of indoor vegetation and natural wood finishes on employee workplace satisfaction.

In illustration, correlations can be made for workplaces with nature views (digital, photographic or through windows), potted plants, direct and indirect sunlight exposure.

Positive correlation to job:

- Job satisfaction and organizational commitment (An et al., 2016)
- Moderated effect of stress on job satisfaction (An et al., 2016)
- 7.4% higher job satisfaction score on average (Dravidge et al., 2008)
- 8.2% higher quality of life score on average (Dravidge et al., 2008; see Appendix B6)
- 3× higher odds of reporting high job satisfaction (Lottrup et al., 2015)
- 2× higher odds of reporting high work ability (Lottrup et al., 2015)

Negative correlation to job:

- Reports of depression and anxiety (An et al., 2016)

FINANCIAL TRANSLATION

Connections to nature have been shown to improve mood, job satisfaction, and energy levels, all of which can reduce the rate of voluntary job separation and associated costs of employee replacement. In particular, existing research shows significant results from indoor and outdoor nature views, daylight, and seating flexibility that offered prospect and refuge conditions. The positive effects of biophilic design on well-being, job satisfaction, and organizational commitment could reduce voluntary job separation rates when compared to non-biophilic offices. Given average financial assumptions and a replacement cost equal to 30% of the employee's salary (Work Institute, 2020), a 10% reduction in job separation from the baseline of 36%, an office of 200 employees would yield a savings of $402,979 in reduced talent acquisition costs per year (see Appendix B7).

D.I.Y. TIPS

» Create a list of priority features for your real estate agent to look for in potential sites.

» Use outreach (survey, etc.) to better understand how employees feel about IEQ conditions and which experience(s) to prioritize in a future refresh.

» Use demo installations to test potential biophilic design experiences, gauge interest and suitability, attract investment, or as a cautionary step before committing a larger budget.

» Incorporate and encourage use of refuge spaces.

» Democratize the space with the best view, adding comfortable seating options.

» Parallel and perpendicular desk orientations may be space efficient, but are not always the most supportive of productivity and stress management—orient desks to optimize view access.

» Use transparent partitions or low partition heights where possible.

» Offer a small budget per employee to purchase plants or personalize their workspace.

» Install indicator lights to inform employees of when it's best to open (or close) their windows, or raise their blinds.

» Offer opportunities for employees to voluntarily care for plants and nature, individually or as a group, that can be conducted during office hours as desired.

» Refer to WGBC (2015) Health Wellbeing & Productivity in offices for what to track and how.

FROM THEORY TO PRACTICE

FOR THE OFFICE WORKPLACE EXPERIENCE

Since the first edition of The Economics of Biophilia (2012), corporate interest in biophilic design for offices seems to be increasing. The emerging understanding of the financial benefits of biophilic and healthful design have already shifted office design and the real estate market. The adoption of biophilic design is accelerating in all types and scales of office spaces, from small tenant improvements to large new towers.

Physical and visual access to nature as well as daylight optimization have become baseline requirements for many lessees and owners. In the Netherlands, office lessee decision-makers have expressed a willingness to accept a price premium of 13%–25% for offices that exhibit higher "health quality", including a 3.14% increase in willingness to pay for offices with views of greenery (Buskermolen, 2019). In New York City, offices with high levels of daylight reportedly yield a 5%–6% rent premium (Turan et al., 2020) while offices with accessible outdoor space are said to rent for 10%–15% higher than those without (Margolies, 2019).

These biophilic characteristics are also strongly established in many prominent green building rating standards for offices, most notably LEED, WELL and LBC. The World Green Building Council has published reports on occupancy surveys and the economic impacts of green buildings in which biophilia is often a targeted component of the design solution. As an example, the Sherwin-Williams office refurbishment in San Salvador, El Salvador, incorporated a variety of occupant health oriented workplace measures, including improved acoustics and indoor air quality, and access to natural daylight for 90% of its workspaces. This approach, while inclusive of more than just biophilic design, led to a 91% occupant satisfaction rate and a 44% reduction in absenteeism from their previous space, amounting to a savings of $85,000 USD per year for the San Salvador location (WGBC, 2018).

At another end of the workplace spectrum, high-stress work conditions in the offices of the U.S. Department of Defence (DoD) led to the development of a series of "salutogenic design" tools, including financially viable "tactical" biophilic design applications, to help provide physical work environments that supported stress reduction and mental well-being for DoD office workers (Brick, 2022). Pre-approved biophilic applications such as green walls, virtual windows and skylights, acoustic tiles and wall panels, glazing films, and synthetic waterwalls are now available online for DoD retrofits and renovation projects.

In 2022, the U.S. Bureau of Labor Statistics confirmed the "Great Resignation" phenomenon—characterized by record voluntary job separation during the COVID-19 pandemic, particularly among firms with fewer than 5,000 employees. The research deduced that, in addition to introducing hourly wage increases and technology (e.g., that enables remote working), a path to dissolving the phenomenon, managing risk, and meeting employee performance objectives is for organizations to "redesign the workplace" (Amanor-Boadu, 2022). Office environments, and corporate ones in particular, continue to lead the way for adoption and innovation of biophilic design as a part of the solution for redesigning the workplace.

A vision for the future of offices is also unfolding—as evidenced by the many new projects that are integrating workplace needs with a hospitality or the feel of home such as with a residential-style living room—to entice employees into not only wanting to return to the office but also benefiting from doing so. Access to windows, outdoor terraces, and indoor vegetation, as well as quiet spaces that provide refuge from disruptions or technology and better enable concentration, relaxation or connection with nature, have become requisite features among leading companies such as Hines, Arcadis, Marriott International, and NI Corp. (Smith, 2023).







ABOVE: LinkedIn Design Lab with dappled light, vegetation, and natural ventilation. Photo courtesy LinkedIn. BELOW: Google Bay View campus with biomorphic forms and patterns, high-back and booth seating, and high-grain wood paneling. Photos courtesy EPA (left) and Winni Wintermeyer (right).

Recognizing the potential of biophilic design to reduce stress, improve workplace satisfaction and differentiate themselves for attracting and retaining talent, tech companies have been early adopters of biophilic workplace concepts.

LinkedIn has tested outdoor workplaces in their Design Lab, Salesforce has applied the 14 Patterns of Biophilia directly to the design of their offices and amenity spaces, and Google has adopted biophilic framework for renovations and new construction projects for their expanding real estate portfolio.

Next-generation workplace design strategies often include biophilic design in one form or another. The offices of Interface and the American Society of Interior Designers (ASID) are case studies that help prove out the economics of biophilia.

BIOPHILIC OFFICE CASE STUDY

INTERFACE BASE CAMP IN ATLANTA, GEORGIA

BIOPHILIC PATTERNS: PROSPECT, REFUGE, MYSTERY, BIOMORPHIC FORMS, MULTISENSORY CONNECTION

Interface took a risk in consolidating all of its Atlanta-based teams from four different properties, along with a showroom, into a three-story, 1950s-era office building in midtown Atlanta. From the outset, the project team knew that the 40,000 square foot building would not be enough space to accommodate a traditional approach of assigned desks and offices. As much of the staff would be moving from diverse workspaces, including highly coveted private offices, adopting an "agile" or flexible workplace model would thus require a shift in workplace culture. If the gamble didn't pay off, additional office space would need to be leased elsewhere in the city, defeating the purpose of consolidation.

Working with Perkins&Will Architects and Integral Engineers, the project team prioritized employee health and well-being for the new headquarters and used an array of biophilic design patterns—prioritizing a balance of prospect and refuge—to create a variety of spatial experiences that would allow for collaboration, private focused time, group meetings, and public events.

Retiring the rigid desk policy and offering more choice—12 workstation types with three seats available per worker—meant that more people would be able to utilize a smaller footprint. With diversity in space type and programming flexibility, Interface employees are able to be where they need to be based on their activity or preference, reportedly choosing to relocate an average of two to three times per day. The project team employed a series of biophilic design features:

- Mystery, through partially revealed views;
- Planters form the boundaries of other spaces;
- A multisensory green roof with aromatic plantings and a water feature visible and adjacent to a rooftop patio and lounge;
- Refuge, through a variety of booths, high-backed carrels, enclosed phone rooms, and designated wellness rooms;
- Complexity & Order, through a pixelated photo of a local forest on 3M film wrapping the building enclosure;
- Prospect, via good views to the forested park across the street; and
- Floor-to-ceiling glass throughout to bring daylight and views to 100% of the workstations.



Content courtesy Interface; photo courtesy Catherine O. Ryan

The building achieved WELL Gold and LEED v4 Platinum certifications. Moreover, in a post-occupancy evaluation conducted by Carnegie Mellon University, (Loftness, et al., 2019) user satisfaction reached the highest level ever recorded by the research team (across a cohort of 75 office buildings) which reportedly contributed to staff retention and perceptions of health as well as expanded capacity for versatile and concurrent activities. Another positive outcome is that this office space was easily able to adapt to post-pandemic workplace expectations while also positioning the office as a place of collaboration and interactions that support Interface's work and culture. Interface is doing more with less through biophilic design.

BIOPHILIC OFFICE CASE STUDY

ASID HEADQUARTERS, WASHINGTON DC

BIOPHILIC PATTERNS: DYNAMIC & DIFFUSE LIGHT, COMPLEXITY & ORDER, MYSTERY, VISUAL CONNECTION

The American Society of Interior Designers (ASID) had occupied a three-story, single-occupant building in the Capitol Hill area of Washington, DC since 1977 and, after a 1998 office fit-out, was due for an upgrade. Upon reviewing the financial costs for undergoing another renovation, and the building being more spacious than was perhaps practical for a collaboration-oriented organization, the ASID National Board of Directors decided to sell the property and move to a new space.

During site selection, the design team, ASID, and real estate broker Savills Studley worked to ensure that the building met the design and wellness goals, which included the reduction of stress and the elevation of cognitive performance and mood among occupants. In 2017, ASID completed a new 8,500 square foot headquarters in downtown DC. Designed as a "Workplace for the Future," the new space features human-centric design elements such as workspace choice, healthy materials, active design, circadian lighting design, and biophilic design.

To paraphrase architects Perkins&Will, biophilic design strategies included patterns that were intentionally employed "to resonate with occupants on a subconscious level and improve their experience in the space":

- Mystery through an "entry sequence designed like a curved path to gradually reveal views";
- Complexity & Order discovered through the abstracted fractal patterns embedded in the window film in the entry corridor;
- Visual Connection with Nature established through indoor biodiversity and exterior views to adjacent rooftop gardens; and
- Dynamic & Diffuse Light experienced through uninterrupted access to daylight from multiple façades.

The project's construction cost was $153 per square foot (which includes costs covering building enhancements that benefit other tenants on the floor) and furniture costs of $28 per square foot (including discounting). Having conducted comprehensive pre- and post-occupancy evaluations of their old office and new headquarters, ASID found significant improvements in scores for absenteeism (-19%), as well as self-reported rates for several metrics: presenteeism (-16%), collaborative working (+9%), workplace attachment (+69%), and overall productivity (+16%). Altogether, the benefits to improved employee productivity and health had financial returns estimated at $694,000 in the first year of operation, for a return on investment of 53%—a payback of just under two years (ASID, 2018).

The new ASID headquarters was the first in the world to simultaneously achieve LEED v3 Platinum and WELL v1 Platinum certifications for commercial interiors. In addition to the immediate and long-term health benefits, the first 15 months of occupancy resulted in an energy savings of $7,636, correlating to 38.2 tons of coal not burned and 72.9 tons of CO2 not emitted. The project is expected to yield a $7M increase in financial impact during the total 10-year lease agreement.



Content courtesy of Perkins+Will, ASID HQ Office case study, ASID Impact of Design Series, Vol. 1, 2018; Randy Fiser, formerly of ASID; Bill Browning of Terrapin Bright Green

FUTURE DIRECTIONS
FOR RESEARCH & REPORTING

While a return on investment for optimizing access to nature—to daylight, greenery, water, the outdoors, and other biophilic interventions—is not as easy to measure as energy savings and solar photovoltaic arrays or high-efficiency water fixtures, the value can be realized through consideration of whether employees want to be in the space.

Research has primarily focused on experiences of:

- Visual connection to nature (generally)
- Indoor vegetation (specifically)
- View quality
- Soundscape

Related to:

- Absenteeism
- Noise distraction
- Workplace satisfaction
- Rent/leasing premiums

In a post-pandemic world, when so many people have had the opportunity to reconnect with nature, office experiences that support that connection are going to be in a better position to attract and retain the best employees. A greater understanding of the relationship between biophilia and workplace outcomes could be expanded to address new research question:

- How perceptions of space have shifted as a result of the COVID-19 pandemic. Does the presence of biophilic design support a better sense of well-being in an office space? Which characteristics and why?
- Research in an educational setting demonstrated that simple interventions—carpet, wallpaper, and window blinds with nature-based patterns—helped academic performance and stress levels (see Determan et al., 2019). How might these types of student-oriented interventions benefit employee occupants in an office setting?



3. EDUCATION

Educational environments are the cornerstone of brain development and expansion of social skills for children and teenagers. Far more than academics, school is where one learns to become a productive and engaged citizen. In these ways, the school environment is perhaps the most influential place outside the home for children and young adults. The U.S. spends over $631 billion on elementary and secondary education annually, with the cost of K–12 education averaging $12,509 per student (U.S. Department of Education, 2017). Despite this significant investment, the U.S. ranks at or below average in multiple subjects (OECD, 2019).

Educational spending is an investment in human capital—in developing the experience, skills, and knowledge of an individual. As with most investments, returns can vary depending on how effectively a given program can encourage healthy psychological development, support creative problem solving, and prepare students for tomorrow's workforce needs. As industrialized states transition from being primarily goods-producing economies to service-, information- and knowledge-based economies, human capital has become an important topic. To this end,

KEY TAKEAWAYS

- Elementary school students in biophilic classrooms and schoolyards have better rates of cognitive development.
- Simple and low-cost biophilic classroom interventions such as carpet, wallpaper and window blinds with biomorphic patterns or textures, can increase academic performance.
- Views and outdoor experiences of nature reduce ADHD symptoms.

FIGURE 3.1. For Quinnipiac University's Health & Wellness Center in Hamden, CT, designLAB architects used biophilic design in the architecture of the building itself to positively impact mental and physical wellness. Courtesy designLAB architects

TABLE 1.3. BIOPHILIA IMPACTS & FINANCIAL INDICATORS FOR EDUCATION

SECTOR	HEALTH & WELL-BEING INDICATORS	FINANCIAL INDICATORS	
		DIRECT	INDIRECT
Education	attention, learning rate	absenteeism, test scores	graduation rates

campus designer Celine Larkin notes that "learning, taken holistically, includes not only skills and specific knowledge, but social and coping skills that underlie future success in the workforce" (Larkin, 2022).

Given the annual financial commitment to public education, it is crucial to ensure every dollar spent contributes to the educational success of students. The physical school environment can play a leading role in supporting educational success. Current studies show that classrooms designed with direct or indirect connections to nature can improve test scores, support mental well-being, and increase learning rates. Research also indicates that allowing children to play and learn in nature can provide benefits like mental restoration, better behavior, and enhanced focus. These outcomes amount to a greater return on investment for the school, the students and their families, and the community at large.

This chapter looks at available research on biophilic design as it relates to stress recovery, learning rates and student performance, as well as graduation rates across a variety of financial indicators for schools and other educational environments (Table 1.3).

LEARNING RATES & ACADEMIC PERFORMANCE

School-age children are expected to wake up far earlier than they are biologically pre-dispositioned for (Healthwise, 2020), remain seated and focused for up to seven hours a day, and do assignments and study in their "free time." The psychological toll of such regimented indoor activity on youth can be significant. In a study of more than 20,000 U.S. high schoolers who were asked how they typically feel at school, 74% responded negatively; the top three most frequently used words to describe how they felt were "tired," "stressed," and "bored" (Moeller et al., 2020).

The adolescent brain is considered especially sensitive to stress, with potential outcomes ranging from altered brain development to cognitive, emotional, and systemic disorders (e.g., McEwen, 2011; Lupien et al., 2009). Moreover, the effects of childhood stress often don't emerge until adulthood (Lupien et al., 2009).

The conventional school environment and curriculum may fall short of mitigating stress and optimizing the learning experience, yet science has come a long way in identifying key design interventions that can do just that.

BIOPHILIA RESEARCH FINDINGS

While curriculum and teaching quality are surely the dominant influence on academic outcomes, the space itself can influence the ability of students to focus, retain information, and develop cognitive capacities. Classrooms with qualitative measures of light, temperature, air quality, flexibility, ownership, complexity, color, and connections to nature have had a demonstrated impact on academic performance (e.g., Barrette et al., 2015). Such qualitative design measures also contribute to a biophilic experience and can support the same academic outcomes. Additionally, outdoor learning programs across hundreds of studies have shown to positively impact learning, knowledge retention, and test performance (e.g., Williams & Dixon, 2013).

Attentional functioning (the ability to focus and stay on task) is a critical component of childhood learning. However, the ability to concentrate and stay on task is a constant challenge and source of stress for many students. Attention Restoration Theory (ART) posits that experiencing nature quiets portions of the brain and leads to better cognitive capacity, including the ability to focus on tasks (Kaplan,1995), and reportedly occurs within as few as 40 seconds of viewing a nature scene (Lee, et al. 2015). Several studies suggest that ART may help explain the positive impacts—stress recovery, environmental satisfaction, attention, cognition, and psychological well-being—on student performance that are experienced when nature and natural analogues are present during classroom learning.

Studies at schools in Baltimore, Michigan, London, Changhua County (Taiwan), and elsewhere reveal that biophilic classrooms can have a significant positive impact on student performance, attention and stress recovery, as well as on attendance, graduation rates, and student evaluations of the teacher and classroom.

STRESS RECOVERY AND SATISFACTION

Visual access to greenery has been found to improve recovery from normal scholastic stresses (e.g., Li & Sullivan, 2016) and improve satisfaction of the classroom environment (e.g., Han, 2009; van den Bogerd et al., 2020).

At the school in Taiwan, the introduction of six plants to one of two classrooms was found to significantly improve satisfaction and well-being among eighth grade students (age 13–14 yrs) in the biophilic classroom; students also rated the biophilic classroom as more friendly, comfortable, and preferred (Han, 2009).

For the year-long study of students in a sixth grade mathematics classroom in Baltimore (age 11–12 yrs), the biophilic interventions were relatively inexpensive, including clutter-free walls, biomorphic patterned wallpaper and carpet, fractal-patterned blinds, and an expanded garden outside the classroom window. According to survey responses, 67% of students in the control classroom rated their stress as being “high” compared to only 35% in the biophilic classroom (Determan et al., 2019). In interviews, students

I THINK THE KIDS CAN SENSE MY ANXIETY... I'VE BEEN TEACHING FOR A LONG TIME IN THE NATIONAL TEST... THIS IS PROBABLY THE FIRST YEAR WHERE I WAS NOT ANXIOUS AT ALL FOR THE TESTING.

MISS B., MATH TEACHER, BIOPHILIC CLASSROOM
GREEN STREET ACADEMY BALTIMORE

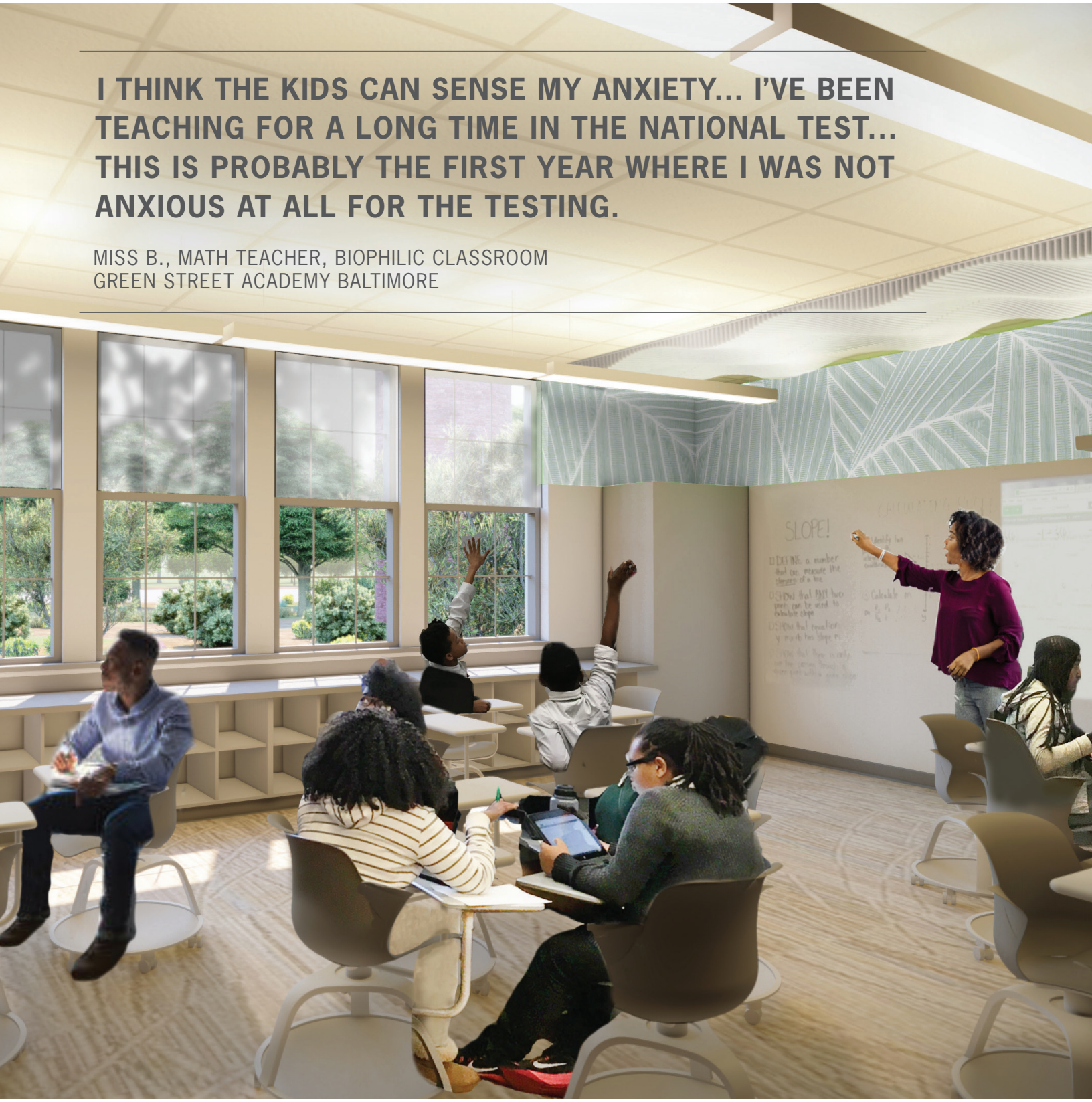


FIGURE 3.2. The Biophilic Classroom study at Green Street Academy in Baltimore, Maryland, introduced biophilic design—biomorphic forms and fractals, complexity and order, and improved views to nature—in ways that resulted in positive and measurable impacts on student stress, sense of calm, and academic performance. Rendering courtesy CGD Architects

in the biophilic classroom reported feeling more relaxed and better able to focus, while the teacher reported that the peaceful qualities of the biophilic classroom made her a more effective teacher (Determan et al., 2019) (see the Biophilic Classroom Case Study for additional perspective).

ACADEMIC PERFORMANCE

In the study of Baltimore middle schoolers, one school year in a biophilic classroom revealed a gain in student test scores 3.3 times greater than those of students in the control classroom (Determan et al., 2019). Similar improvements to test scores have been demonstrated across a range of student ages and subjects of study; by way of views to nature (Benfield et al., 2015); through outdoor-based curriculum (Wells et al., 2015); and by correlation with an overall amount of healthy vegetation around schools (Wu et al., 2014).

PERCEPTION, ATTENTION AND ENGAGEMENT

High school students with views to vegetation have reportedly scored 13% higher on attentional functioning tests than those with a barren window view or with no window (Li & Sullivan, 2016). Exposure to stream and fountain water sounds have had measurable impacts on attentional functioning and short-term memory, with bird song and non-lyrical music also correlating with improvements to cognition (Shu & Ma, 2019).

A study of first-year college students (age ~19 yrs) reported that those students with a view to nature perceived the course subject matter to be more important and the instructor to be more enthusiastic than those without the view to nature (Benfield et al., 2015). It is also worth noting that photo documentation for this study suggests that students sat with their back to the windows.

Another study looked at the influence of indoor plants on students—at a university, a secondary school, and a secondary vocational school—during a single lecture. Across these three field experiments, the presence of plants in the classroom was found to improve attentional functioning, student evaluations of teachers and lectures, and overall classroom preference. However, the study also indicated that attending only one lecture in a vegetated space was enough to (van den Bogerd et al., 2020), suggesting that nature needs to be part of the overall learning experience and not just a momentary encounter.

The Baltimore study also revealed that students in the biophilic classroom had a significantly more positive perception of the space and the curriculum, and their self-reported level of involvement increased by 20% (Determan et al., 2019). These outcomes can be likened to research on outdoor learning, where lessons taught in nature have been found to improve classroom engagement when compared to standard classroom-based lessons (e.g., Kuo, Browning & Penner, 2018).



FIGURE 3.3. The design of the stairs at Quinnipiac University's Health & Wellness Center in Hamden, Connecticut, uses high grain wood finishes, dynamic light and spatial geometries to enhance the stair climbing experience. The project was a Finalist for the 2023 Stephen Kellert Biophilic Design Award. Image courtesy designLAB architects

In the study of lessons taught in nature, teachers reportedly had to redirect students' attention half as frequently, allowing them to teach uninterrupted for twice as long (Kuo, Browning & Penner, 2018).

Research is also exploring implications for students with learning differences. After exposure to settings with varying degrees of vegetation, children diagnosed with attention deficit hyperactivity disorder (ADHD) have reportedly experienced a 15% greater ability to concentrate after walking in a highly vegetated setting compared with a less vegetated urban or neighborhood settings; the impact of a walk among vegetation on a child's concentration was found to be roughly equal to the peak effect of two common ADHD medications (Taylor & Kuo, 2009).

In one final example, independent of student demographics, students at primary schools with more tree canopy in the school yard exhibited the greatest increase in working memory over those in the baseline. Assessing outcomes over twelve months across 36 elementary schools in Barcelona revealed that students with access to more densely treed schoolyards have measurable improvements of cognitive development over the average rate for their age group. Groups with the greatest exposure to tree canopy at home, on the commute to school, and around their school demonstrated a compounding improvement in working memory (5%), superior working memory (6%), and reduction in inattentiveness (1%) above improvements made by groups with less exposure to greenness (Dadvand et al., 2015).

Together these studies seem to indicate that students in biophilic settings are less stressed, more engaged, pay better attention, perform better, and have a preference for those spaces to boot.

FINANCIAL TRANSLATION

Graduating from school is a significant but far from comprehensive indicator of a student's academic success. Actual cognitive and psychological development attained as a result of schooling, and the corresponding influence on a graduate's economic and social outcomes later in life, are also critical indicators of success.

The quality of schooling as it relates to human capital development has vast implications for a region's economic development. By one estimate, increasing student test scores by a quarter of a standard deviation would yield an average increase of 5.2% of discounted GDP above what is anticipated based on current achievement. The resulting increase would more than cover the entire U.S. expenditure on public education—approximately 4% of GDP (Hanushek, Ruhose & Woessmann, 2017).



FIGURE 3.4. Biophilic principles were embedded in the architectural design, building form, and materials choices, as well as the furniture and finishes for the ecological primary school De Verwondering Almere, in the Netherlands. Designed by ORGA Architect, in collaboration with Gemeente Almere, Lüning, Projectum, Goed Geplant, and Vannorel, the project was a recipient of the 2023 Stephen Kellert Biophilic Design Award for the Europe and Global categories. Courtesy ORGA Architect

GRADUATION RATES

One repercussion of having a negative high school experience is that many students stop attending. In the U.S. 2018–2019 academic year, about one in seven students did not receive a high school diploma (U.S. Department of Education, 2021). Meanwhile, the rate of poor mental health among college and university students has reached such a point that campuses are confronting it head-on with changes to physical infrastructure and building design, among other measures, to support healthy stress management, and to reduce risk of poor performance, drop-outs and self-harm.

This correlation between a poor school experience and a high drop-out rate also highlights a potential opportunity. According to numerous sources, including the National Center of Secondary Education and Transition (NCSET), an improved school experience may increase the rate of retention as students move through the education system (Lehr et al., 2004). Early detection and mitigation of unnecessary stress and anxiety in the elementary and secondary school experiences may help to reduce such repercussions—and associated indirect costs to families and communities—before students reach tertiary education and adulthood. Biophilic design may have a role to play in making this possible.



FIGURE 3.5. Much like seeing a natural wonder or walking into a place of worship, the Law Library at the University Michigan provides a sense of awe that can change a person's mental outlook. Courtesy Mathew Schwartz on Unsplash

BIOPHILIA RESEARCH FINDINGS

The quality of education can vary greatly by state and locality. An analysis of national standardized test scores of American eighth graders found that the top-performing state (Minnesota) was at a level equivalent to three grades above the lowest performing state (Mississippi) (Hanushek, Ruhose & Woessmann, 2017). Yet, state-wide 2018–2019 graduation rates are nearly identical, at 84% and 85%, respectively (NCES, 2021).

The study at the school in Taiwan analyzed objective measures of well-being and found students in the classroom with vegetation had significantly fewer sick days and fewer behavioral incidents leading to punishment (Han, 2009). In Michigan, views to the outdoors were found to correlate with graduation rates. By assessing student exposure to nature in more than 100 high schools (while matching economic and racial demographics), one study found that the amount of nature in view from a school window, the size of classroom windows, and the objective density of landscape vegetation each had a significant positive association with a student's likelihood of graduating and their plans to attend a four-year college (Matsuoka, 2010). In contrast, "featureless" landscapes with mowed lawns and parking lots were associated with poorer student performance (Matsuoka, 2010; Kweon et al., 2017), as well as lower graduation rates, fewer plans to attend a four-year college, and greater criminal activity (Matsuoka, 2010).

FINANCIAL TRANSLATION

Students who do not complete high school typically earn $9,984 less per year than high school graduates and $33,956 less per year than four-year-college graduates (Bureau of Labor Statistics, 2017). Across the country, those income disparities add up quickly. The national graduation rate in the U.S. for the class of 2015 was 83.2%. By one estimate, had the graduation rate for that class reached 90%, the national economy would have benefited from an additional $5.7 billion in gross domestic product (GDP) by the career midpoint for those students (Alliance for Excellent Education, 2018).

FROM THEORY TO PRACTICE

FOR THE EDUCATION EXPERIENCE

Conventional thinking has often separated K–12 education and community vitality; however, research tells us that students who perform better in school are more likely to graduate, pursue higher education, obtain employment, and give back to their communities. While specific outcomes vary from school to school and community to community, the perspective of funders, policy researchers, and advocates may be shifting to acknowledge that school performance is intricately linked to the economic vitality of a community.

As these stakeholders look for solutions to improve school performance, one other option is outdoor schooling. Outdoor learning is increasingly recognized for its benefits to students' information retention, attentional functioning, social development, and ability to buffer psychological stressors (e.g., Kuo, Browning & Penner, 2018). What is referred to as *udeskole* in Denmark, or curriculum-based outdoor learning, has seen large-scale adoption and standardization across Europe. One study found 14% of Danish teachers practice *udeskole* on a weekly or bi-weekly basis (Bentsen & Jensen, 2012). Nordic countries, often considered champions of outdoor learning in schools, consistently rank among the highest on standardized test scores and overall student outcomes (OECD, 2018).

Such practices are beginning to take root in American schools as well, with more than 250 nature-based preschools and kindergartens nationwide—an increase of 66% in just one year, and years before the advent of the COVID-19 pandemic (North American Association for Environmental Education, 2017). The estimated 10,000 children enrolled in these programs spend around three-quarters of their time learning outdoors, compared to the country's tens of millions of American children who, other than a 15–45 minute recess (which form many is in an asphalt playground devoid of nature), spend their entire school day indoors.

Colleges and universities are turning to biophilic design to address increasingly prevalent symptoms of school-induced stress and anxiety on students and instructors. At the campus scale, the University of Virginia has engaged in a multi-departmental assessment of how and where biophilic campus planning strategies might improve the health and safety of students and educators alike.

At the building scale, the Windhover Contemplative Center at Stanford University promotes reflection, refuge, and recovery for the Stanford community. The building's design creates a powerful interplay of artwork and the surrounding landscape, allowing individuals to "offset the personal cost that can be entailed by students, faculty and staff striving to reach the pinnacle of their fields" (Stanford University, n.d.).

D.I.Y. TIPS

Students and teachers alike benefit from biophilic educational experiences. Inspiration from nature can be used in many ways to help do this; here are a few low-barrier entry points.

- Allow students to orient their desks to face the window while studying, testing, or during other independent activities.
- Use floor tiles or carpet with a fractal or biomorphic pattern.
- Install window blinds, ideally with a fractal pattern, that allow some light to filter through.
- Install indicator lights to inform teachers and students of when it's recommended to open (or close) their windows, or raise their blinds.
- Permit teachers to limit educational material on the walls to just a few things.
- Use the school's outdoor campus and landscape as a teaching/learning tool.

BIOPHILIC CLASSROOM CASE STUDY

GREEN STREET ACADEMY BALTIMORE

BIOPHILIC DESIGN PATTERNS: BIOMORPHIC AND FRACTAL FORMS & PATTERNS, DYNAMIC & DIFFUSE LIGHT

In an effort to understand the impacts of learning space design on learning outcomes for middle school students, Green Street Academy in West Baltimore, Maryland, underwent a year-long study in partnership with Craig Gaulden Davis Architecture, Terrapin Bright Green, The Salk Institute, and Morgan State University. The hypothesis was that students would perform better in classrooms with fractal patterns and biomorphic design elements.

The biophilic classroom was enriched with views to nature, dynamic and diffuse daylight, and biomorphic fractal patterns with four interventions: a wallpaper frieze with a palm leaf pattern, Interface carpet tiles with a curving collinear pattern, Mechoshade fabric window blinds imprinted with a fractal dappled tree shadow, and reduced clutter (i.e., quantity of "learning material") from the walls.

The study revealed that the biophilic enhancements were strongly associated with reduced student stress and enhanced learning outcomes: test scores were three times better than those of students in that same classroom a year prior (i.e., before the classroom was enhanced). Students and teachers alike reported feeling calmer in the biophilic classroom. The teacher experience shifted to facilitating learning rather than managing behavior.

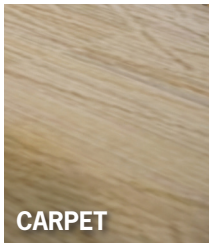
The biophilic interventions were simple and low cost—flooring, window blinds, wall decor. These components are also common interventions among most classroom renovations and new builds, and can thus be specified as biophilic options from the outset, rather than as costly additions.

With biophilic interventions, and subsequent improved outcomes and satisfaction, scaled to all classrooms, improved teacher retention and student success are both likely to occur. Communities that advocate for, fund, and design biophilic schools and classrooms can, in the longer term, benefit from increased positive contributions by students to the community and the economy.











SOURCE: Determan, J., Akers, M.A., Albright, T. Browning, B. Martin-Dunlop, C., Archibald, P. & Caruolo, V. (2019). Impact of Biophilic Learning Spaces on Student Success. Images courtesy Craig Gaulden Davis Architects

BIOPHILIC CLASSROOM CASE STUDY

PUTNEY HIGH SCHOOL LONDON

BIOPHILIC DESIGN PATTERNS: VISUAL CONNECTION WITH NATURE, REPRESENTATIONAL NATURE

The aim of a pilot study at the Putney Girl's High School in London was to understand the benefits of biophilic classrooms for (1) occupant comfort, (2) occupant well-being, and (3) reduction of indoor particulate matter and VOCs. The project involved three six form classrooms. All three classrooms had the same view out to trees; the main differences were the intervention and the classroom subject. Living potted plants were introduced into the Maths classroom (nature in the space), a photographic mural of woodlands into the English classroom (natural analogues), and nothing into the third classroom (control).

The study results indicated that nature in the space (i.e., living plants) had a stronger relationship with occupant cognitive well-being, and that a natural analogue (i.e., photographic mural of a nature scene), was a preferred biophilic intervention and had a stronger relationship with occupant emotional well-being.

While this was not an intensively executed project, the low-cost interventions and resulting data further validate the more robust research, and can help school leadership visualize what's possible at their school.



"NATURE IN THE SPACE" CLASSROOM



"NATURAL ANALOGUES" CLASSROOM

SOURCE: Clare Bowman, Richard Bowman, & David Bowman (2019, August). The Biophilic Classroom Study. Putney High School Girls' Day School Trust. https://www.gdst.net/publications/the-biophilic-classroom. Images courtesy Putney Girls' Day School Trust

FUTURE DIRECTIONS
FOR RESEARCH & REPORTING

Learning environments characterized by biophilic experiences can clearly lead to better learning outcomes, with benefits that accrue to both students and their communities.

Research to date focuses on:

- Biomorphic patterns
- Views and visual connections with nature
- Physical access to nature
- Daylight access

Related to:

- Cognitive development and performance
- Test scores and scholastic achievement
- Behavior
- Satisfaction

Already apparent is the growing concern that well endowed schools and educational institutions are better positioned to offer their students, faculty and staff with quality biophilic environments—highlighting the risk of widening the existing socioeconomic privilege gap. With this in mind, research that further validates the viability of low-cost, off-the-shelf biophilic solutions is certainly a priority. Additionally, an understanding of the relationship of biophilia and scholastic outcomes could be expanded in several research areas:

- Social skills, collaboration, creative thinking, problem solving, risk taking, future discounting, prosocial behaviors (generosity, humility).
- Distinction of similarities and differences in outcomes for different age groups.
- Teacher retention, workplace satisfaction, perceived productivity, and student teachability/receptivity to learning.
- Curriculum-based outdoor learning versus book learning, cost-benefit analysis of learning rates and knowledge retention.
- Validation of research on educational settings that demonstrates simple interventions aimed at helping academic performance and stress levels (see Determan et al., 2019).
- Learning differences, such as among neurodivergent populations, and receptivity to biophilic learning environments.
- What is needed for biophilic design criteria to be factored into public school design standards.

EDUCATION



4. HEALTHCARE

Healthcare is an essential service, and experience of society. Quality healthcare offers people a better chance to reach their full potential and live long, productive, and high-quality lives. On an average day, there are approximately 91,000 people admitted for inpatient care nationally (American Hospital Association, 2022).

In 1960, U.S. healthcare spending accounted for 5% of the national gross domestic product (GDP), whereas in 2018, spending was closer to 17.7% of GDP, or $3.6 trillion (CMS, 2019). The significant cost burden—due in part to Americans using more healthcare services as well as the increasing cost of those services—is by some estimates 60% higher than the average cost across comparable countries (Koechlin, Lorenzoni & Schreyer, 2010).

Healthcare environments are much like restaurants, spas, hotels and resorts in the hospitality industry—in essence, spaces for the care of guests (albeit guests who would rather be elsewhere). Increasing cost of service has put pressure on the healthcare industry to become more efficient. For many facility administrators, that has meant a departure from the idea of hospitality. However, a sacrifice in quality could be detrimental to a healthcare facility's (HCF) financial viability.

KEY TAKEAWAYS

- Patients with views to nature report less pain and exhibit lower stress levels.
- Biophilic measures that lead to shorter hospital stays enable higher patient turnover, thereby increasing the number of patients that can be treated without increasing bed capacity or staffing.
- Views and access to nature help lower staff absenteeism and burnout, which may contribute to heightened workplace satisfaction and reduced turnover.

FIGURE 4.1. Inspired by Roger Ulrich's 1984 study, Khoo Tech Puat Hospital in Singapore was designed by CPG Architects as a community amenity that provides patients with views to multiple gardens. Courtesy Bill Browning

TABLE 1.4. BIOPHILIA IMPACTS & FINANCIAL INDICATORS FOR HEALTHCARE

SECTOR	HEALTH & WELL-BEING INDICATORS	FINANCIAL INDICATORS	
		DIRECT	INDIRECT
Healthcare	healing rate, analgesic intake	patient turnover, staff retention	visitor perception

As early as the 1970s, the negative effects of outside deprivation and windowless health service facilities were being documented (e.g., Wilson, 1972). Several contemporary studies have shown a direct, positive relationship between quality performance (including positive perception of the hospital experience and safely carrying out procedures) and profitability (Beauvais et al., 2019; Richter & Muhlestein, 2017). This relationship continues to strengthen as new programs tie hospital reimbursements to quality performance stipulations, and as the prevalence of reviews and ranking systems increases (Barnes et al., 2017; Bai & Anderson, 2016).

HFCs include a broad range of service types—such as general acute-care hospitals, psychiatric and addiction treatment centers, dialysis to dental clinics, assisted living facilities and hospice homes, among others—for which there are a number of examples around the world of biophilic design application. Despite this diversity in practice, most research as it pertains to biophilia is centered around inpatient care at hospitals.

Biophilic design offers opportunities to improve the experience of patient's rooms, choices of artwork, fabric and carpet patterns can introduce biophilic elements. Patient evaluations according to room design appeal have revealed 6.1% higher patient satisfaction for rooms defined as being more appealing—featuring wood furniture, decorative art, carpeted floors, and crown molding (Swann, Richardson & Hutton, 2003). Those patients also reported a better overall hospital experience and a greater likelihood of reusing the hospital (+4.75%) and recommending it to a friend (+3.4%) (Swann, Richardson & Hutton, 2003).

Current research suggests that a central psychological and physiological need of patients and staff is exposure to nature and natural systems. Studies of healthcare settings that have incorporated small biophilic elements have illuminated significant improvements to patient health outcomes, environmental perceptions, pain medication use, stress, and staff performance. The upfront cost premium that biophilic design elements may incur are often outweighed by recurring cost savings and increased revenue stemming from reduced patient length of stay, allowing higher patient turnover, improved public relations and customer loyalty, and a more productive and happy workforce.

This chapter looks at available research on biophilic design as it relates to patient length of stay (LoS), patient experience, and staff well-being and performance, primarily though not exclusively at inpatient hospitals, across a variety of financial indicators for hospitals and other environments where healthcare services are provided (Table 1.4).

INPATIENT LENGTH OF STAY

To remain financially viable, hospitals aim to maximize the number of patients they serve annually (to increase revenue) and minimize the patient's visit time (to reduce expenses). Increasing the number of "customers" served per year is far more important for a hospital than for many non-healthcare service providers because the vast majority of costs for a hospital are fixed. More patients means a slight increase in total costs (e.g. food, medical supplies) but a major increase in revenue. Thus, a hospital's patient bed turnover rate (BTR) is an important indicator of performance efficiency.

In this way, improved patient healing rates don't just represent qualitative success for hospitals; they also present an opportunity to increase revenue and profit margins. For each day of a patient's recovery, per diem expenses (e.g., staff pay, food, room maintenance) add up and can both decrease profitability of a patient's operation and lower the number of tests and operations a hospital can perform each year. Average Length of Stay (ALoS), a metric for approximating a patient's healing rate, is key to managing operational efficiency, as it is often regarded as a top determinant of profitability; on average, hospitals with a lower ALoS have a higher profit margin (Bai & Anderson, 2016).

For this reason, reducing stress for patients ultimately can improve an HCF's bottom line. Stress can affect a patient psychologically, physiologically, biochemically, and behaviorally; it suppresses immune function, slows healing processes, and heightens emotional reactions (APA, 2006; Segerstrom & Miller, 2004)—higher stress levels among patients may result in a higher ALoS. For instance, the wounds of non-stressed patients have been shown to heal 24% faster than those of patients under stress (Kiecolt-Glaser et al., 1995).

BIOPHILIA RESEARCH FINDINGS

In 1984, Roger Ulrich conducted what would become a foundational study for biophilia research; he measured the influence of a view of nature scenery on patients recovering from gallbladder surgery. Some patient rooms had views to a cluster of trees and bushes, while others faced an exterior brick wall of another wing of the hospital. After accounting for other variables, Ulrich's findings showed that patients with a view of nature had positive impact on three indicators of performance:

- Shorter postoperative hospital stays,
- Lower rates of pain medication consumption, and
- Fewer negative evaluative comments from nurses.

On average, the patients whose windows overlooked the nature scene were released after 7.96 days, while patients with the view of the brick wall stayed 8.71 days—an 8.6% (0.75 days) decrease in ALoS (Ulrich, 1984), which amounts to shortening the inpatient stay by 18 hours.



FIGURE 4.2. The Shin-Kashiwa Clinic in Kashiwa City, Chiba Prefecture, Japan (northeast of Tokyo), is a three-story multi-use building with a 120-bed dialysis clinic. The building design was in response to the client's philosophy that "a good treatment environment heals the patient's mind and leads to mental and physical health." The architects "aimed to design the clinic so that patients not only have their bodies cleansed, but can also find peace of mind." The design combines floor-to-ceiling views of nature and fire-resistant laminated wood structure to intentionally create an indoor-outdoor forest bathing experience for out-patients undergoing treatment. The Japanese Cypress wood panels on the interior and exterior ceiling also provide a 'warm' scent. The project is a recipient of the 2017 Good Design Award. Designed and constructed for Nakazatokai Medical Corporation by Takenaka Corporation (2016). Photo courtesy Takenaka Corporation.

Since Ulrich's pioneering study, a broader range of research topics has substantiated the relationship between patient room design and healing rates including lighting quality and indoor vegetation. Every 100 lux increase of daylight illuminance has been shown to reduce patient length of stay by 7.3 hours (Joarder & Price, 2013); patient rooms varied by as much as 500 lux, corresponding to a 36.5 hour average reduction in ALoS for those in the brightest versus darkest rooms; and, irrespective of daylight levels, having a view to the outside reduced ALoS by 17.4 hours (Joarder & Price, 2013).

Patients in rooms with indoor vegetation have reportedly recovered from thyroidectomy surgery 5% faster than those with no plants in their rooms (Park & Mattson, 2009); those patients with indoor plants also required significantly less pain medication while recovering.

FINANCIAL TRANSLATION

According to the Agency for Healthcare Research and Quality, the average hospital expense per inpatient recovery day was $2,143 in 2016 (Ellison, 2019). Considering that the average U.S. hospital conducts 5,809 inpatient operations annually, those per-patient cost savings quickly multiply. Across all studies that were reviewed for this report, reductions in patient LoS due to biophilic interventions ranged from 4.9% to 33.3%, with an average decrease of 18.1%, or 1.0 days. The annual savings for a hypothetical hospital due to fewer per diem expenses would thus be approximately $12,363,559 (see Appendix B2). Furthermore, with a higher inpatient turnover rate, the hospital has greater capacity at a given time to treat more patients, which would in turn sustain higher annual profit margins.

PATIENT EXPERIENCE

Upon entering an HCF, patients may already be stressed from acute or chronic trauma, connotations of hospitals, personal cost of care, or anticipation of test results. Conventional healthcare environments may and often do exacerbate a patient's stress. This is especially true when facility design limits the user's ability to alter or control environmental conditions, fails to provide positive distraction or manage noise disturbance, or is inadequately daylit to enable healthy immune function, stress hormone regulation, and sleep patterns (Ulrich et al., 2006).

Improved patient experience has been found to correlate with greater profitability (i.e., higher net operating margin and higher revenue per patient) (Richter & Muhlestein, 2017). The reason for this correlation is a combination of increased revenue due to improved customer satisfaction, positive word of mouth and new customers, and reduced costs from shortened lengths of stay and fewer medical errors (Rust, Zahorik & Keining-Ham, 1995).

POSITIVE DISTRACTION

Humankind's evolutionary predisposition for nature connectedness has been hardwired to notice and dwell on nature experiences, not blank walls. Distraction theory submits that "positive views" can help lessen the perception of pain by diverting attention away from the source (Brewer & Karoly, 1989). The best "positive distractions" are those of evolutionary importance to humans. The sound of running water, for instance, has been shown to very effectively capture attention and impart a sense of tranquility (see "An Ear for Nature" by Browning & Walker, 2018).

Natural landscapes with water, especially those providing prospect and refuge, were the ideal habitat for early humans so it is no surprise that we have a strong affinity for those scenes. Effective nature paintings, photographs and window views are both interesting and non-threatening (Kellert, 2008).

The public relies heavily on reviews and surveys when choosing which hospital to visit. Hospital prestige—ranked by the US News & World Report Best Hospitals Honor Roll—is also a strong predictor of higher profit (Bai & Anderson, 2016). With "patient experience" ratings included in this honor roll ranking system, the association between prestige and patient experience is much stronger.

Quality of service increasingly impacts the financial viability of a hospital. The Hospital Value-Based Purchasing program (VBP), as part of the Affordable Care Act of 2010, directly ties public and private payer reimbursements to improvements in quality performance (Beauvais et al., 2019). With patient experience—quantified by standard evaluation surveys—comprising 25% of the quality performance score, approximately half of U.S. hospitals now have a direct financial incentive to improve the patient experience (Center for Medicare and Medicaid Services, 2021).

Another important factor of a patient's hospital experience is their perception of pain, also a component of the VBP's patient experience assessment (Richter & Muhelstein, 2017). Pain perception is psychologically mediated and can be influenced by changes in the patient's environment or sensory experiences (Vincent et al., 2010). This may help explain why medical staff who find their work "meaningful" reportedly impart higher levels of satisfaction among patients served (e.g., Healthstream, 2017), and why positive views can help lessen the perception of pain (Brewer & Karoly, 1989; see sidebar on Positive Distraction). In turn, pain perception can influence how patients also perceive staff and the hospital environment, as well as their likelihood of returning to or recommending the facility.

BIOPHILIA RESEARCH FINDINGS

Research suggests that building and interior design can influence a patient's environmental satisfaction, perceptions of staff, and overall mental well-being. Most hospital visitors who spend time in a hospital garden reportedly feel more relaxed and calm, less stressed, and more able to cope with their circumstance (e.g., Cooper Marcus & Barnes, 1995).

VIEWS

Patients with a simulated sky view on the ceiling have reported an average of 12.4% higher environmental satisfaction and were found to have 53.4% lower acute stress levels and 34.79% lower anxiety (Pati et al., 2015). Positive views of nature have been shown to reduce perceived pain levels (Ulrich, 1999; Vincent et al., 2010). In testing a patient's pain perception, viewing images characterized by prospect-refuge spatial conditions has resulted in significantly lower reported pain than all other view conditions, with or without nature, while viewing a blank wall resulted in significantly higher total pain scores than other view conditions (Vincent et al., 2010).

INDOOR VEGETATION

Indoor foliage has also been shown to improve environmental satisfaction and overall patient experience in hospitals. Researchers studying patients recovering from appendectomies in hospital rooms with and without vegetation, have found significant differences in pain perception, pain medication use, psychological well-being, and hospital evaluations (Park & Mattson, 2008). By day three of post-operative recovery, patients in rooms with plants took significantly fewer pain medications and reported conspicuously lower rates on four indicators of pain perception and psychological well-being:

- Pain intensity (-9.8%),
- Pain distress (-10.0%),
- Fatigue (-10.1%), and
- Anxiety (-20.7%).

Those patients also evaluated their rooms as being more satisfying, relaxing, comfortable, colorful, pleasant smelling, calming, and attractive than did patients in the control rooms. On average, patient evaluations for those recovering in rooms with indoor vegetation were 10% higher than for those without vegetation; and when asked about a willingness to return to this hospital, patients in vegetated rooms gave a positive response rate of 20 percentage points higher (Park & Mattson, 2008).

FINANCIAL TRANSLATION

Biophilic design interventions appear to correlate with positive patient outcomes like greater well-being, pain management, and healing rates. These outcomes are in turn associated with better hospital evaluations, increased customer loyalty, and improved public perception of the HCF.

Biophilic interventions have been shown to improve patient evaluations from 6.1% to 12.4% (Pati et al., 2015; Swan, Richardson & Hutton, 2003; Park & Mattson, 2008). According to Richter and Muhlestein (2017), the correlation between patient experience and profitability is such that for every 1.0% increase in the percentage of people who would “definitely recommend” the hospital, the hospital is expected to net an increase of $247,000 in income, $1,072,000 in patient revenue, and a 0.04% in operating margins. A hypothetical hospital that implements biophilic design interventions to improve the inpatient experience could experience a 3.4% increase in willingness to recommend (Swann, Richardson & Hutton, 2003), which would net a $3,644,800 increase in patient revenue and a 0.14% increase in net operating margins (see Appendix B3).



FIGURE 4.3. The canted position of the hospital beds at Jacob's Medical Center in La Jolla, California, allows the patient a direct view to the outside while still enabling their face to be visible to medical staff passing in the corridor. Photo courtesy CannonDesign

STAFF WELL-BEING & PERFORMANCE

Hospitals have significant labor costs, which comprise approximately 55% of total hospital costs (Daly, 2019). Improvements in healthcare labor force productivity can significantly sway a hospital's overall profitability. Two of the greatest hindrances to productivity among medical care providers and technicians is stress and burnout. The prevalence of stress and burnout among hospital staff has direct financial implications in the form of costs associated with medical errors, staff turnover, and poor patient evaluations.

Nurses who rate themselves as being in suboptimal health reportedly may have a 26%–71% greater likelihood of making medical errors than healthier staff (Melnyk et al., 2018). According to a study by Melnyk and colleagues (2018), 54% of surveyed nurses reported being in suboptimal physical and mental health, and about half had made at least one medical error in the past five years.

Medical errors are said to cost the U.S. approximately $20 billion per year (Andel et al., 2012). By some estimates, the costs associated with replacing a single nurse is two times the nurse's pay, while the cost of nursing turnover can be equal to 5% of a hospital's average annual operating budget (Hall, 2005).

BIOPHILIA RESEARCH FINDINGS

Medical staff can recover from stress more easily and perform better when provided with routine access to gardens, views, and sunlight.

VIEWS

In one study, 43.75% of surveyed nurses reported zero hours of exposure to an outside view during their 12-hour shift (Pati, Harvey & Barach, 2008). The study went on to document impacts of views on well-being. Of the nurses whose attentiveness remained the same or improved throughout the shift, 60% had had exposure to outdoor views, predominantly views of nature. Of those whose attention deteriorated, 67% had had no exposure to views. A similar effect was observed for acute stress (Pati, Harvey & Barach, 2008).

Shepley and colleagues (2012) analyzed patient and medical staff outcomes within an intensive care unit (ICU) in New Hampshire before and after a redesign that improved window views and daylighting. While the staff remained consistent from the old ICU unit to the new one, average annual absenteeism per employee reduced 39.5%, from 38 hours to 23 hours; medical staff vacancies per year also decreased 25%, from 10.12% to 7.49% (Shepley et al., 2012).

BREAK SPACES

More recently, research efforts are questioning the impact potential of break spaces on medical staff, including the difference between indoor and outdoor break spaces. In one such study, evidence suggested that taking breaks in an outdoor garden was potentially more beneficial than in an indoor break space in mitigating burnout among nurses, and particularly in addressing emotional exhaustion (Cordoza et al., 2018).

FINANCIAL TRANSLATION

As a means to reducing costs associated with staff turnover and boosting profit margins, biophilic design interventions can target real and perceived well-being, performance, productivity, and workplace satisfaction among medical staff. An improvement in the attitude and emotions of staff can impact patient experience which also has financial implications (see Financial Translation for Patient Experience). Assuming average staff turnover rates cost hospitals 5% of their annual operating budget (Hall, 2005), if the hypothetical hospital were to experience a 25% reduction in staff turnover (Shepley et al., 2012), the hospital would stand to recapture 1.25% of its operating budget (see Appendix B4). Biophilic experiences that help reduce the frequency of medical errors could also yield significant savings, but are harder to reliably quantify.

FROM THEORY TO PRACTICE

FOR THE HEALTHCARE EXPERIENCE

In the last few decades, the healthcare industry has shown positive momentum toward prioritizing patient and staff experience and creating restorative indoor and outdoor environments. Evidence-based design for healthcare settings combines current healthcare design research with the physiological and psychological needs of patients, doctors, and staff (Hamilton & Watkins, 2009). Publicly available databases exist as repositories for best practices in HCF design (e.g., The Center for Health Design's Knowledge Repository). "Salutogenic design", or design that supports positive health, has also emerged as an approach to bringing together environmental conditions and health-positive design solutions. Biophilic design is essentially one subcategory or lens used when taking a salutogenic approach to evidence-based design for HCFs.

Healing gardens have become a common type of biophilic design intervention to provide patients with a greater sense of control, physical movement, and access to nature as a positive distraction (Cooper Marcus & Sachs, 2014; Domke, 2008). For medical caregivers, having access to a lush, green outdoor area may make their already precious downtime more restorative; this may also translate to better talent recruitment and retention rates and improved task accuracy. Horticulture therapy and healing gardens for patients have been directly credited with reducing patient and staff stress, reducing patient medication use, and increasing staff satisfaction (Sadler et al., 2008).

The planning and design of out-patient facilities for testing, procedures or treatments, such as dialysis clinics (where patients sit or recline for 3-4 hours at a time multiple times a week), is beginning to optimize for visual connections with nature such as through views, daylight and use of wood materials to reduce stress, support restoration and shift perception of the facility from being a place to go when ill, to a place to go to heal. For patients who have the option to choose between clinics, the biophilic experience may be a differentiator.

Interior biophilic design interventions are also increasingly incorporated into HCF design and tend to be applied to very targeted spaces and audiences:

- Outdoor views from patient beds and on-site contemplative spaces, such as at the University of California–San Diego's Jacobs Medical Center.
- Natural daylight, low partitions, outdoor terraces for staff, as at The Zev Yaroslavsky Family Support Center in Los Angeles.
- Prospect and refuge spatial conditions, as at Maggie's Centre Leeds, Royal Melbourne Hospital, and Mount Sinai Hospitals (see the Healthcare case study).

In addition to views and daylight, biophilic design interventions incorporating natural materials, artwork, digital (false) windows, sunrooms, and restoration/ contemplation rooms are each becoming more common, though still far from standard practice.

D.I.Y. TIPS

Biophilic design can be used in many ways to help do this; here are a few low-barrier entry points.

- Orient seating in waiting areas to face vegetation or views.
- Soften corners to enable people to see around them.
- Orient patient beds to view outside from a recumbent position.
- Outside, increase biodiversity of plantings, add seating, a water feature and shading. Quality over quantity.
- Ensure medical staff break rooms have access to refuge and nature—if not real nature, then digital.

BIOPHILIC HEALTHCARE CASE STUDY

RECHARGE ROOMS AT MOUNT SINAI HOSPITALS

BIOPHILIC PATTERNS: MULTISENSORY CONNECTIONS WITH NATURE, REFUGE

Spaces for meditation, reflection, prayer, yoga, and other restorative activities are an increasingly common building amenity, particularly in civic or high-density spaces like airports, hospitals, universities, and office buildings. Their utilization rate can be influenced by many factors, one of which is design. An economic justification for allocating space for restorative activities can be made by accounting for the financial implications of a stressed labor force.

With the goals of addressing trauma, anxiety, and stress to help combat burnout and improve cognitive performance among healthcare workers, the Abilities Research Center within the Mount Sinai Health System collaborated with Studio Elsewhere to design Recharge Rooms as semi-private immersive biophilic spaces. These Recharge Rooms included vegetation, seating, and user controls for customizing ambient scent, lighting, soundscaping and digital visual stimuli. The rooms were installed at eight Mount Sinai locations as part of the COVID-19 pandemic response effort in early 2020. During a two-week period, 562 frontline healthcare workers scheduled time in the Recharge Rooms, and 219 were surveyed by a neuroscience team at Mount Sinai before and after a single 15-minute experience. Among those surveyed, self-reported stress levels reduced by an average of 59.6% (Putrino et al., 2020).

The benefit of time spent in the Recharge Rooms spread by word of mouth among healthcare workers. Recognizing the value of the experiment, Mount Sinai and other hospitals are now actively looking to relocate this temporary pandemic-era amenity to a permanent space within their respective facilities—accessible to healthcare workers year round. In addition to the health benefits, it is conceivable that a thoughtfully designed Recharge Room may offer a competitive advantage to healthcare facilities wanting to attract and retain top talent. In the two years since the first Recharge Room was conceived, Studio Elsewhere has installed more than 60 Recharge Rooms at hospitals around the country.



Recharge Rooms at Mount Sinai healthcare facilities offer a menu of experiences from which healthcare workers can select. Photos by Maksim Axelrod for Studio Elsewhere

BIOPHILIC HEALTHCARE CASE STUDY

STROKE UNIT AT ROYAL MELBOURNE HOSPITAL

BIOPHILIC PATTERNS: PROSPECT, REFUGE

For the design of the new Stroke and Neurology Unit at Royal Melbourne Hospital (RMH), architects ClarkeHopkinsClarke integrated patterns of biophilic design with a central, circular walkway concept to get stroke patients active within 24 hours for the best chance of recovery. According to project architect Nicholas Simmonds, in addition to having large windows and abundant natural light, curved forms, timber joinery, and other "elements of home," the design optimizes sightlines and incorporates comfortable seating nooks that support staff, patient, and visitor interaction while allowing easy observation and communication by clinicians.

The "racetrack" walkway, high patient–staff ratios, sightlines (i.e., prospect views), refuge seating, accent features, and navigability together form a cohesive strategy. As the biophilic experience was integral to the design concept of the Stroke Unit, the economic value cannot be parsed out and attributed to any singular design measure, yet the impact of the design on patient recovery, cost, and staff satisfaction has been significant. The Stroke Unit experiences 90% patient satisfaction from one month to another; stroke patients come away functioning better than they did previously for the same length of stay; and more patients are being discharged directly home who would previously have had to go on to rehab or a nursing home.

According to Professor Mark Parsons, head of the Stroke Unit and Director of Neurology at RMH, being able to send one stroke patient home to live independently instead of to a nursing home for further rehabilitation can save the community upwards of $200K the first year and $100K each year thereafter. RMH treats about 1,000 stroke patients a year, a number that is gradually increasing. Parsons estimates that preventing 10 patients a year from going to a nursing home will cover the cost of the Stroke Unit.







SOURCES: HospitalHealth.com; ClarkeHopkinsClarke
Photos © Rhiannon Slatter

FUTURE DIRECTIONS
FOR RESEARCH & REPORTING

Many of the research outcomes from inpatient hospitals are likely to be directly applicable or adaptable to other types of healthcare facilities, but that will not always be the case. Outpatient facilities may benefit from research outcomes from other sectors such as retail, offices and hospitality.

Research in healthcare has primarily focused on experiences of:

- Visual connection and access to nature
- Representational nature through art and digital mediums

Related to:

- Inpatient recovery times
- Medication intake
- Staff burnout
- Workplace stress and anxiety among medical staff

While there are ample studies that bring perspective to the potential impact opportunity for biophilic design interventions in HCFs, few research initiatives measure the same variables, making it difficult to build robust datasets for the healthcare sector.

New research is needed, including:

- Impacts on night time shift workers
- Outpatient-focused interventions and impacts, as well as whether they differ from those for inpatients
- Multisensory experiences (most research is limited to aromatherapy)
- Applicability of specific interventions across HCFs and service domains.
- Studies that parse out the impact of specific variables related to design interventions, such as by having biophilic spaces and control spaces.



5. RETAIL

Since the advent of profitable retail e-commerce (c. 2000) retailers have been questioning the relevance of the physical store. The last two decades have been a period of significant upheaval in the retail sector; between 2009 and 2019, the share of retail sales from e-commerce more than doubled. Then, in 2020 alone—paradoxically due to and despite the pandemic—e-commerce spending grew another 44% (US Census Bureau, 2021; Ali, 2021). The dramatic shift to online shopping is forcing retail brands to rethink the value proposition of brick-and-mortar stores relative to online shopping. One such value is in the secondary reasons a person chooses to shop: people shop to buy products but also to escape everyday stressors, enjoy new settings, and experience something exciting, novel or nostalgic. On these fronts, e-commerce cannot compete.

When analyzing data from the 2008 financial crisis and years following, management consulting firm McKinsey & Company found that brand leaders

KEY TAKEAWAYS

- Biophilic design in retail settings that offer immersive experiences are able to connect customers to the brand in ways that cannot be replicated online.
- The presence of vegetation and animals positively influence a person's purchasing behaviors including increased likelihood of entering, dwelling in, and returning to a store.
- The presence of street trees can increase willingness to pay.

FIGURE 5.1. Glossier Pop-Up in Seattle, WA, features natural analogues and a perception of mystery that draws customers into the store. Photo courtesy Studio Lily Kwong via Dezeen

TABLE 1.5. BIOPHILIA IMPACTS & FINANCIAL INDICATORS FOR RETAIL

SECTOR	HEALTH & WELL-BEING INDICATORS	FINANCIAL INDICATORS	
		DIRECT	INDIRECT
Retail	customer attention, brand perception	staff retention; hedonic value, sales	dwell time, return patronage, social media attention

in customer experience saw shallower downturns, faster recovery, and three times higher long-term shareholder returns compared with market averages (Briedis et al., 2020). Not surprisingly, customer experience has shifted to become a center point for in-store retail brands. Business forecasters at KPMG predict that "experience per square foot" will soon become a key performance indicator used by retail brands (KPMG, 2018).

The atmosphere in a retail space (e.g., music, scent, visual stimuli, aesthetics) has long been recognized for its influence on customer experience and subsequent shopping behavior (e.g., Bohl, 2012). In 1973, American economist and marketing expert Philip Kotler coined the term Atmospherics, defining it as the "conscious designing of … buying environments to produce specific emotional effects in the buyer that enhance [their] purchase probability" (Kotler, 1973). Toward this goal, retail space design serves many practical functions from a marketing standpoint. Effective exterior design elements first need to attract attention and interest new customers, while interior design aims to elicit greater exploration, product engagement, and purchases. Both exterior and interior retail design can contribute to a positive perception of the brand and acceptance of pricing of its goods and services.

While there are many factors that influence decision making while shopping, there is evidence that biophilic design changes the equation to support outcomes such as greater attention, dwell time, brand perception, purchasing behavior, and return visits. It's no coincidence that many stores and malls are laid out to intentionally and meticulously guide shoppers through a maze of products surrounded by strategically placed planters, trees, and skylights. Whether intuitive or intentional, the sector has long leveraged our innate affinity for the savanna-like environments of our ancestry: clustered trees, semi-open spaces, refuge from the sun, water features, view corridors, and high levels of visual access (Heerwagen, 1998). Such practices only scratch the surface of potential benefits to customers and retailers alike; by tapping into the nature-based influencers of consumer perceptions, behaviors, and purchasing habits, biophilic design can be applied toward helping retail stakeholders attract new customers, capture greater profits, and remain relevant in this fast-changing sector.

This chapter looks at available research on biophilic design as it relates to customer perceptions (e.g., of a brand, product, store, shopping experience) and shopping behavior across a variety of financial indicators in stores and other types of brick and mortar retail environments (Table 1.5).

CUSTOMER PERCEPTION

Inextricably linked to our recollection of familiar brands are the many feelings, connotations, and perceptions that the brand and its products and services evoke. Companies invest large sums to craft the right appeal, as perception can influence the acceptable price for a product, loyalty or patronage behavior, and rate of word-of-mouth referrals (Donovan & Rossiter, 1982; Sherman, Mathur & Smith, 1997; Lam, 2001).

In an extensive analysis of 306 stores of the same women's apparel brand, a one-point increase in customer evaluation scores (on a seven-point scale) corresponded with a 15% increase in customer spending per store visit and a 16% increase in annual store sales growth (Maxham, Netemeyer & Lichtenstein, 2008).

The release of dopamine, one of the strongest neurochemicals in the human brain, that occurs in reward-oriented experiences in nature—such as viewing a Japanese water garden—can also occur in retail environments. These experiences are perceived as being pleasurable. In Retail (r)Evolution (Kepron, 2014), brand guru David Kepron explains that our willingness to dwell in, explore, and purchase from a retail environment is determined at the subconscious level by countless factors. Kepron describes how we select one product over another as being a "complex neurobiological event" that's influenced by these many factors, including the design of the retailing experience (Kepron, 2014). In other words, the perception of pleasure while shopping is directly tied to purchasing decisions and retail environments that are able to trigger the release of dopamine.

BIOPHILIA RESEARCH FINDINGS

While designing the human experience of retail, venues can actively influence the feelings and experiences a customer associates with the brand. Biophilic design—with its capacity to reduce stress and to enhance perceptions of immersion, restoration and pleasure—has been shown to be particularly effective at imparting a positive and memorable experience to customers. A number of studies look into the qualitative biophilic characteristics impacting the customer experience.

NATURE OUTSIDE THE RETAIL SPACE

Dr. Kathleen Wolf was an early explorer of the impacts of vegetation on retail perceptions and patronage. Across several of her studies, research participants were asked to rank four qualitative measures of given retail environments:

- Visual quality,
- Place perception (judgment of products, product value, and merchant responsiveness),
- Patronage behavior (frequency and duration of shopping actions), and
- Price perception.













FIGURE 5.2. Much of the retail at Jewel Changi Airport in Singapore aligns with the mall's overarching nature theme. While some venues rely heavily on views to the plants and water vortex, others incorporate organic shapes or fractal patterns, wood materials, refuge seating, unique lighting conditions, and other patterns of biophilic design. The storefront and interiors of the Japanese restaurant chain, Tempura Makino (lower right), combines mystery conditions and views to vegetation with natural materials, complexity and order, and diffuse lighting that lures patrons into a biophilic dining experience. © Catherine O. Ryan



Figure 5.3. At The Tao of Tea—nestled in at the far end of Lan Su Chinese Garden in the heart of Old Town, Portland, Oregon—ample shade trees, water, koi fish, meandering pathways, decorative stonework, and ornate Chinese architecture often means seating, for enjoying tea and mooncakes, can be hard to come by. Photo courtesy Catherine O. Ryan

With each recurring study, well-tended streets with large trees received the highest preference ratings for visual quality—even though plants obscured some products and building façades—while tidy business districts with no trees received the lowest scores (Wolf, 2003; 2004; 2005). For place and price perceptions, results revealed that consumers preferred trees as attractive and appealing additions to their shopping experience and ranked these streets as well-maintained, friendlier, and more worthy of their dollars than the barren or enclosed sidewalk streets. Other research (e.g., Joye et al., 2010) has indicated that customers are more likely to travel to and shop at stores with street trees. Wolf's third study revealed that respondents viewing images of vegetated retail settings indicated that acceptable prices to pay were 15% higher for specialty shopping (e.g., gift for a friend), 20% higher for convenience shopping (e.g., sandwich), and 25% higher for general shopping (e.g., new jacket) (Wolf, 2005).

NATURE IN THE RETAIL SPACE

Research on indoor experiences of vegetation and biomorphic (decorative) elements have similar influences on customer judgment of interior design, products, and staff as they pertain to five notable perceptions:

- Stress reduction,
- Expectation of engagement with the store and merchandise,
- Service quality and satisfaction,
- Pleasure, and
- Restoration (defined here as fascination, comfort, ease, escape).

For example, the addition of greenery to an image of a "complex" store (i.e., one with higher density of visual information) significantly increased perceived pleasure and alleviated feelings of stress; participants likewise reportedly expected to have greater engagement with the store and merchandise in the complex store when vegetation was present (Brengman, Willems & Joye, 2012).

In a study of simulated service settings, the addition of just one potted plant was associated with significantly higher ratings of perceived service quality, service satisfaction, and pleasure—especially for participants with lower exposure to plants in their everyday life; displaying a biomorphic vase in place of a potted plant increased ratings in comparison to the control room, but not as much as did the room with a potted plant (Tifferet & Vilnai-Yavetz, 2017).

In a study of shopping plazas, the biophilic plaza—with lush vegetation, birds flying overhead, and dramatic waterfalls—was significantly more likely than a non-biophilic plaza to engender feelings of fascination, comfort, ease, and escape. Furthermore, these perceptions occurred more often with vegetation, even when the shopper was there to buy a specific item rather than to browse (Rosenbaum, Ramirez & Camino, 2018).



FIGURE 5.4. The trend toward creating biophilic spaces has penetrated retail showrooms as well as online brand presence. Vignettes and mock spaces that connect customers to nature through wood furniture, biomorphic carpet patterns and indoor vegetation—living or preserved—are often showcased in relatable compositions, indulging perceptions of what's possible at home or in the workplace. Photo courtesy Home Depot

FINANCIAL TRANSLATION

There appears to be a direct link between customer perception and a store's bottom line whereby improved perceptions of a store can increase patronage, as well as the price people are willing to pay for merchandise and the amount spent per visit. Applying the results from Maxham, Netemeyer and Lichtenstein (2008) to the research by Wolf (2005) indicates that introducing biophilic design to a retailing environment, in a manner that improves customer perception and evaluation scores by one point, has the potential to increase revenue per item by 15%–25%. For an average U.S. small business, this would amount to approximately $80,000 of increased annual revenue (see Appendices B2 and B3).

SHOPPING BEHAVIOR

Ultimately, it is the decisions that customers make—whether to enter a store, how long to stay, whether to purchase an item—that determine a retailer's success. Ideal shopping behaviors have been well detailed by the marketing sector and with tools that leverage neuromarketing, defined as "the measurement of physiological and neural signals to gain insight into customers' motivations, preferences, and decisions" (Harrell, 2019), a more accurate picture of the many factors influencing shopping behaviors is emerging. For instance, shopping behaviors are linked with a customer's particular emotional state; experiences of pleasure while shopping can promote "approach behavior" (e.g., Vilnai-Yavetz & Rafaeli, 2011), while a state of heightened attentiveness can increase "buying intentions"



FIGURE 5.5. A third of Athleta's storefront at this New York City location is dedicated to nature imagery as a means of communicating their people-planet-business ethos. Photo courtesy Catherine O. Ryan

(e.g., Bagozzi et al., 1999). In essence, when shoppers are happy and stress-free, and have a visual interest in the interior space, they are better customers for retailers.

BIOPHILIA RESEARCH FINDINGS

Attracting passersby is a key strategy for store marketing and the reason behind eye-popping window displays. A biophilic window display can be an effective measure for enhancing attention toward the store and encouraging greater exploration behavior. Shopper-reported patronage, dwell time, willingness to pay, and likelihood of repeat visits—accurate reflections of spending habits—increase when vegetation is heavily prevalent (Wolf, 2005).

As an illustration, when an aquarium is visible in a storefront window (not a pet shop, in the case of this research), the proportion of people strolling through a mall who stop in front of that storefront has been shown to more than double (from 3.3% to 8.5% of passersby) and linger for a longer duration (median duration increase of 16%); prospective customers are also twice as likely to return to a store that has an aquarium in its storefront window (Windhager et al., 2011).

Research has underscored the impact of biophilic design (e.g., plants, animals, water, refuge) on large shopping centers, with customers showing a greater intention to visit (Ortégon-Cortázar & Royo-Vela, 2019) and more optimized behaviors (from a sales perspective) when in the act of shopping, including:

- Slower walking speeds when passing by a biophilic areas (+12.2% of customers);
- More frequently entering biophilic areas (+28.8%);
- Greater average dwell time (+279%); and
- Greater rates of exploration, as measured by physical contact with products (+139%) and staff interactions (+311%) (Buber et al., 2007).

Data also suggests that the effect on consumer behavior may differ with each type of biophilic design feature. For example, walking speed correlates with a presence of water and sight protection (refuge), whereas the rate of entering a biophilic area correlates with the presence of living plants, and duration of stay is shown to be particularly influenced by the presence of animals (Buber et al., 2007).

FINANCIAL TRANSLATION

Several customer behaviors have demonstrable impact on a store's financial performance. Foot traffic—the number of shoppers a retailer can attract into the store—is of notable importance. Using data from 41 women's apparel stores of the same brand, a conservative increase of one unit in average traffic per hour has been shown to correspond to an increase of $9.97 (at the time of the study), or $12.45 (in 2022 dollars) in average hourly sales volume (Perdikaki, Kesavan & Swaminathan, 2012). This estimation is particularly relevant to Buber and colleagues (2007), who reported that 28.8% more people entered a biophilic retail area than a traditional shopping area.

Assuming a modest increase of one additional person per hour to store traffic after a biophilic redesign, that store could theoretically anticipate an increase of $43,100 in revenue per year (see Appendix B4) or, in illustration of scale, $1.905 million per annum for a chain of 50 stores that each offer a biophilic experience.

D.I.Y. TIPS

It pays to make the retail experience one to which customers are attracted and stay loyal. Biophilic design can be used in many ways to help do this; here are a few low-barrier entry points.

» Think of the storefront as a portal to a new and alluring experience.

» Resist filling the storefront with of marketing or product that blocks daylight from entering the store.

» Incorporate vegetation, nature sounds and other biophilic features or movement in the storefront window.

» Enable customer engagement with the multisensory experience of the brand and product(s) on display.

» Create a sense of discovery through arrangement of aisles, or with scent, sound, and lighting.

FROM THEORY TO PRACTICE

IN RETAIL EXPERIENCES

Sluggish consumption and fierce competition have challenged the industry in recent years, fueling large-scale restructuring and store closures. Pop-up shops and temporary "Instagram-worthy" interventions have since emerged in various forms—many of which are distinctly biophilic, with vegetation, wood materials, biomorphic forms, and dynamic ambient lighting—as a way to capture consumers' attention and reassert brand differentiation. Such applications of biophilic design as a marketing tool can be observed at shopping malls, markets, showrooms, boutiques, cafés, and streetside restaurants alike.

BIOPHILIC RETAIL CASE STUDY

SHOPPING MALLS: 360 MALL KUWAIT

BIOPHILIC PATTERNS: PROSPECT, VISUAL CONNECTION WITH NATURE, PRESENCE OF WATER

From seasonal interventions to full renovations, shopping mall interiors are trying to infuse life, turning to nature to attract customers and even help them lose track of time. Strong examples of biophilic shopping destinations include The Jewel at Changi Airport in Singapore and the 360 Mall in Kuwait.

Owned by Tamdeen Shopping Centers, the 360 Mall in Al Zahra, Kuwait, was built as a contemporary indoor shopping center in 2009 and expanded in 2016. According to urban planners CallisonRTKL, the design approach to the expansion was to create an immersive environment that would be "a stand-out destination" relative to a larger nearby competitor, and to "drive increased sales" for tenants. To help achieve these goals, the design team leveraged research from The Economics of Biophilia (1st ed., 2012) to employ strategies that, in their words, would "deliver the kind of psychologically soothing and calming effects of nature that have been proven to draw shoppers into stores, lengthen dwell time, and boost sales" (O'Grady, 2016). In collaboration with botanist Patrick Blanc and others, the project included ample daylighting, a revamp of the food lounge interiors with vertical gardens, a new garden court, and a 10-meter-high water feature interspersed with seating. To further validate the biophilic design strategy, these interventions intentionally supported goals for building performance—including humidity control, air quality, and solar heat gain—which also impacts the mall's operational economics.

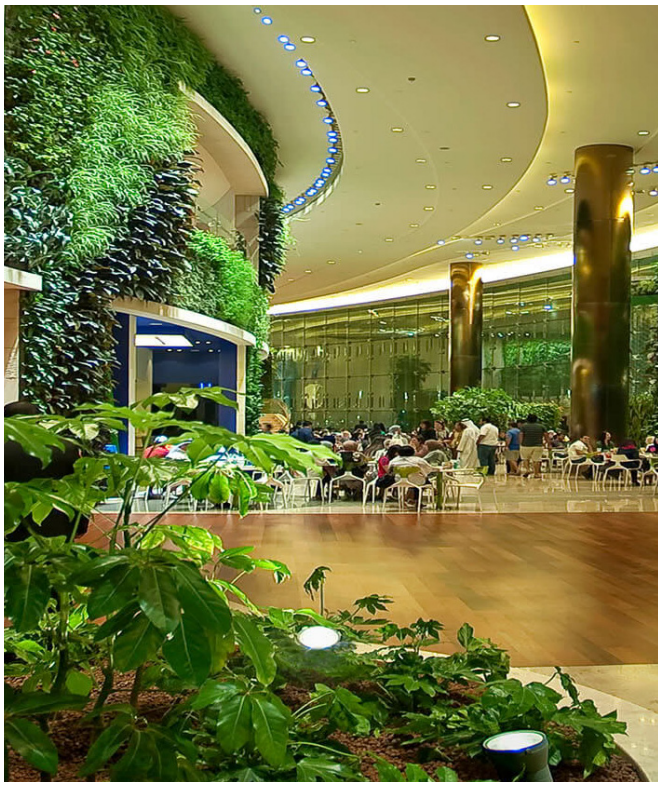


Photo and narrative content courtesy CallisonRTKL

BIOPHILIC RETAIL CASE STUDY

PUBLIC MARKETS: GRAND BAZAAR ISTANBUL

BIOPHILIC PATTERNS: PROSPECT, MYSTERY, COMPLEXITY & ORDER

The public market where independent vendors control just one of many, if not hundreds, of owner-operated stalls, is a retail archetype that has gone through a historic revival in the last decade. Prominent examples include Chelsea Market in New York, Pike Place Market in Seattle, Chatuchak Weekend Market in Bangkok, and the Grand Bazaars of Istanbul and Tehran. Core to the identity of public markets is the experience each one provides—the twists and turns induce perceptions of mystery with a multisensory experience of sights, scents, and sounds that urge exploration, discovery and possibly awe.

Because of the low barriers to entry, public markets have always been a hotbed for showcasing the unique crafts and goods of the locality, a celebration of culture and place. While the concept of a marketplace has been around for thousands of years, the emphasis on an authentic celebration of place strongly aligns these marketplaces with experience-oriented retail. The marketplace is now increasingly framed as a key component of community planning, likened to any other essential urban infrastructure. In the span of about two decades, a fivefold increase in the number of farmers' markets has occurred in the U.S. (ULI, 2016). Even though it's mostly small businesses that occupy the halls and stands, this retail trend is big business; in a year, over 9 million people are estimated to visit Chelsea Market in New York City—between 28,000 and 35,000 visitors daily (ULI, 2016).

Founded in 1461, the Grand Bazaar in Istanbul, Turkey, is the world's largest covered market. Over its 500 years, the market has endured several fires, ebbs and flows in investment, and an expanding customer base. Today the 330,452 ft2 (30,700 m2) market covers 60 streets and receives more than 91 million visitors a year. The winding alleyways with recurring instances of compression and release, are rife with multi-sensory experiences identifiable in the presence of spice and herb scents, variations of light and shadow and sound, of complexity and order in navigation and product placement, and of prospect and mystery and awe.

The continued interest and connection to this type of public market over millennia is a testament to basic principles of biophilic design; markets are an illustration of the human ecosystem. The successful ones allow for an organic pattern of development (complexity and order), with dynamic lighting conditions, thermal and airflow variability, winding corridors that elicit perceptions of mystery, historic detailing that often includes natural analogues. Altogether, these characteristics encourage customers to explore, engage, unwind, and to return again and again.



Photo courtesy Ramon Vermij on Pixabay; data courtesy GrandTurkishBazaar.com

BIOPHILIC RETAIL CASE STUDY

SPECIALTY STORES: GLOSSIER, INNISFREE, AESOP, BASS PRO, RH

BIOPHILIC PATTERNS: VISUAL CONNECTION, BIOMORPHIC FORMS, MATERIAL CONNECTION, DYNAMIC LIGHT

Brands with biophilic or nature-inspired goods and services are using store design and decor to connect consumers with their products. For direct-to-consumer brands that predominantly operate from online sales, such as for health and beauty products, flagship showrooms and temporary pop-ups add to both brand recognition and secondary sales revenue.

Biophilic design is frequently being used to establish or reinforce brand identity. **Innisfree**, a cosmetics company that uses natural ingredients sourced on Jeju Island in Korea, has used a variety of biophilic design measures in their stores. Innisfree cafés, such as in Manhattan in New York and in Myeondong and Gangnam in Seoul, are known for carrying that nature connection from their product ingredients to their immersive biophilic retail experiences, including ceilings that mimic clouds, cascading plants and living green walls, wood or fractal patterned surfaces, dynamic lighting, and projected landscapes.

Aesop also creates immersive experiences that use similar design patterns to Innisfree, but with completely different aesthetics and in a way that differentiates itself from other brands. Aesop "sensoriums" in Oslo, Geneva, Sao Paolo, Vancouver, Bondi Beach and elsewhere are good examples of refuge, mystery and connection to place created through biomorphic forms, natural materials, complexity and order, dynamic lighting and other patterns of biophilic design.



Innisfree Seoul. Photo courtesy SOFTlab



Glossier Pop-Up Seattle. Photo courtesy Studio Lily Kwong via Dezeen

Glossier, another cosmetics company that predominantly sells online, worked with landscape architect Lily Kwan to create a pop up location in Seattle that featured moss mountains and living flowering plants, resulting in an immersive interior experience of nature despite the relatively small size of the space.

Outdoor gear retailer **Bass Pro/Cabela** constructs large scale themed environments that may feature waterfalls, fish ponds and other habitats inside their big box stores, literally bringing the outdoors inside; while the outdoor gathering spaces and rooftop dining at **Restoration Hardware** (Atlanta, New York City, Los Angeles) are an example of biophilic design contributing to brand destination identity.

FUTURE DIRECTIONS
FOR RESEARCH & REPORTING

The impact of biophilic design interventions targeting customer perception and purchasing behavior are likely to vary across brands, industries, and markets.

Research to date focuses on:

- Indoor and outdoor vegetation
- Street trees
- Storefront Design
- Daylight

Related to:

- Sales
- Shopping behaviors directly and indirectly related to sales
- Pricing (perceived value and willingness to pay)

RETAIL

Any business with a proven ability to adapt over time, such as in the face of financial crises or changing market demands, conveys a sense of authenticity and economic resilience. This perspective begs the question of what the intentional incorporation of biophilic design might do to further validate the economics of a shopping destination, and for the benefit of retailers and investors as well as for customers and employees.

Retail is one of the more challenging sectors to find financial data relative to biophilic design interventions. While there are some good early studies on the impact of daylighting on retail sales (e.g., Romm & Browning, 1995; Heschong, 1999), few if any current financial examples are available to the public. This is likely due to a reluctance to share such data (to protect a competitive advantage) or because it simply isn't tracked.

Smaller stores and boutiques that undergo refreshes do not necessarily track the financial performance of before and after conditions relative to specific design interventions; whereas for chain stores and franchises, the challenge may be with adhering to brand standards (a challenge also familiar to the hospitality sector) that don't inherently support biophilic interventions, or with not having before-and-after scenarios to study (a practice perhaps more familiar to the commercial office sector).

As retailers increasingly differentiate themselves by providing enhanced customer experience, the degree to which shoppers feel immersed, away (mentally and physically escaped from ordinary responsibilities), and restored are likely to become indicators of perceived value and willingness to spend. There is also anecdotal evidence (e.g., Buber et al., 2007) that biophilic stores and shopping malls are likely to have higher sales relative to comparable non-biophilic shopping venues, though such metrics have not been directly studied.

With these gaps, limitations and perspectives in mind, new research might consider the following scenarios and focus areas:

- Economic performance data framing **before-and-after** (renovation or refresh) scenarios at a store, including metrics such as foot traffic, sales, customer purchasing behavior; pricing; staff retention and workplace satisfaction; social media attention.
- **Side-by-side** pop-up stores that are identical with respect to underlying brand(s) and product(s), differing only in that one store incorporates biophilic design in the storefront and/or interiors.
- Financial implications of **temporary or permanent** retail experiences at multiple stores (though not all) within a single brand/franchise as a comparison (of before-and-after, as well as side-by-side),
  - Baseline variables (spatial layout, product/service, operational practices) remain constant
  - Accounts for store (co)location factors, demographic differences, holiday calendar year/month/day, staffing and operating hours, and other variables that would otherwise confound a comparative financial analysis.
- Impact(s) of **non-vegetal** biophilic design interventions.



6. HOSPITALITY

Each year, 1.3 billion room nights are booked in the U.S. alone (Oxford Economics, 2019). With a clientele growing in both number and expectations, and disruptors like Airbnb and emerging hotel subscription models stoking competition, the hospitality industry has gone through significant changes in the past few decades. For economic viability, the ideal hospitality design would not just maximize occupancy and price per room but would also impart a memorable guest experience that creates life-long loyalty and keeps guests and visitors engaged and spending time and money on-site.

Each year, 1.3 billion room nights are booked in the U.S. alone (Oxford Economics, 2019). With a clientele growing in both number and expectations, and disruptors like Airbnb and emerging hotel subscription models stoking competition, the hospitality industry has gone through significant changes in the past few decades. For economic viability, the ideal hospitality design would not just maximize occupancy and price per room but would also impart a memorable guest experience that creates

KEY TAKEAWAYS

- Guest rooms with views to nature can be sold at a higher rate.
- Biophilic hotel lobbies with food and beverage retail that encourage dwell time can increase total revenue per available room.
- Gen Y travelers are more likely to book rooms at hotels that have visual appeal on social media. Hotels hailed as being among "the most Instagram-worthy" are more likely to include biophilic design elements, excellent views to nature, or both.

FIGURE 6.1. Nature immersion and wood structures, and elevated prospect views to the pool and Andaman Sea round out the wholly biophilic experience at the Amanpuri resort in Phuket, Thailand. Photo by Bill Browning

TABLE 1.6. BIOPHILIA IMPACTS & FINANCIAL INDICATORS FOR HOSPITALITY

SECTOR	HEALTH & WELL-BEING INDICATORS	FINANCIAL INDICATORS	
		DIRECT	INDIRECT
Hospitality	staff performance, perception of place	average daily room rate (ADR, RevPAR)	total revenue per available room (TRevPAR), employee satisfaction, brand loyalty, social media attention

life-long loyalty and keeps guests and visitors engaged and spending time and money on-site.

Meanwhile, preferences are changing; Gen Y travelers—now accounting for 70% of all hotel stays—expect bespoke experiences, local cultural connection, and visual "wow" (Barkley Inc & FutureCast, 2016). Concurrently, demands for mental restoration and wellness have created new markets in wellness tourism and, along with the growing prevalence of remote working, have contributed to competition in the hospitality sector. The market for wellness tourism has surpassed $639 billion and the World Travel & Tourism Council's (WTTC) 2021 report on emerging consumer trends predicts that the focus and spending on travel related to self-care, wellness, and stress relief will continue to grow in the foreseeable future (WTTC, 2021; Yeung & Johnston, 2018).

Hotel guest rooms, lobbies and amenities, as well as web presence, have each been targeted for brand innovation and differentiation. Over the past decade, studies have shed light on the powerful impact of biophilic design on not just the guest experience but also on guest preferences and perceptions. From design motifs, vegetation, natural materials, views to nature, and other means of creating connections to place, biophilic design is measuring up to be a flexible and profitable strategy for hotels.

This chapter looks at available research on biophilic design as it relates to hotel guest room rates and guest perception, and to hotel lobbies, amenities and dwell time across a variety of financial indicators for hotels and resorts and other hospitality oriented service venues (Table 1.6).

GUEST ROOM RATES

The first introduction to a hotel typically occurs online. Eighty percent of Gen Y travelers use online booking sites like Priceline and Expedia to make lodging arrangements (AARP, 2016). Hotel images, often seen for mere seconds, are one of few sources of information prospective customers have to infer the quality, experience, and overall worth of a hotel. Given the fast pace of browsing, those images must also be memorable enough to stay with the consumer as they browse other options. Ninety seven percent of Gen Y shares their travel experiences on social media and are more inclined to stay at a hotel that is Instagram-worthy over one that offers a fair price (Hyde, 2021).

WELLNESS TOURISM

Wellness tourism is defined by The Global Wellness Institute (GWI) as "travel associated with the pursuit of maintaining or enhancing one's personal well-being"—this includes proactive efforts "to maintain a healthy lifestyle, reduce stress, prevent disease, and enhance… wellbeing" (GWI, 2021).

Servicescapes in wellness tourism and hospitality in general may include design and experiential elements aimed at restoring cognitive capacity and mood, such as to boost guests' attention, preference and, subsequently, service consumption behaviors (Purani & Kumar, 2018).

Depending on the type of hospitality venture, these biophilic servicescapes can be a tool for supporting wellness tourism, enhancing guest experiences and, ultimately, leading guests to spend more time and money on site and sharing positive memories on social media.

By one analysis, room booking revenue generates 68% of a typical hotel's total revenue (Mandelbaum & McDade, 2017). Hotel administrators work to increase revenue per available room (RevPAR) by maximizing occupancy rates and the average daily rate (ADR) for rooms, both of which can be influenced by a hotel's aesthetics; in one study, aesthetics explain 48% of the variation in consumers' booking intentions (Baek & Ok, 2017). In another study, a one-unit increase in the perceived "character" of a hotel's interiors (both guest rooms and public spaces) was shown to predict a 0.8% increase in a hotel's ADR, and a one-unit increase in the perceived "urban and social integration" (e.g., references to local habitat or culture) was shown to predict a 1.3% increase in a hotel's ADR and a 1.4% increase in RevPAR (Zemke, Raab & Wu, 2018).

BIOPHILIA RESEARCH FINDINGS

NATURE IN ADVERTISING

A first strategy for improving RevPAR is to optimize the online information available for a hotel. Particular components in photos have been shown to influence consumer emotion, cognition, and behavior.

In one study, the inclusion of nature imagery (e.g., a beech tree meadow, oak forest, African savannah with trees, a mountain stream, lakes, Mediterranean coastline) in advertising elicited positive emotional responses on participants, similar to what might be felt when experiencing in person such a natural environment; these emotional responses differed heavily from when experiencing an environment devoid of nature, such as an urban space or rocky desert, shown in advertising (Hartmann, Apaolaza & Alija, 2013).

In a follow-up study, using eye-tracking software and a memory test, the research team found that those viewing nature scenes in advertising spent a longer period of time viewing advertising messaging and had higher scores on messaging recall and recognition tests (Hartmann, Apaolaza & Alija, 2013).

NATURE VIEWS

More directly applicable to hospitality, views to nature and the presence of indoor vegetation have been shown to impact visual appeal. But what creates this visual appeal? The most ubiquitous connection to nature emphasized in hotels is a room's view. Several studies have found significant price premiums for real estate with views; however, few studies have taken aim at hotel rooms. One of the most direct assessments of price premiums associated with view characteristics in hospitality was conducted by Terrapin Bright Green in collaboration with Interface and Gensler. Analyzing 100 hotels around the world, the paper found an 11% premium for an urban hotel's average daily rate for a room with a view—in particular, a water view—compared to rooms with other types of views (Browning et al., 2016). For resorts, the price premium was even higher, at 18% for rooms with views.

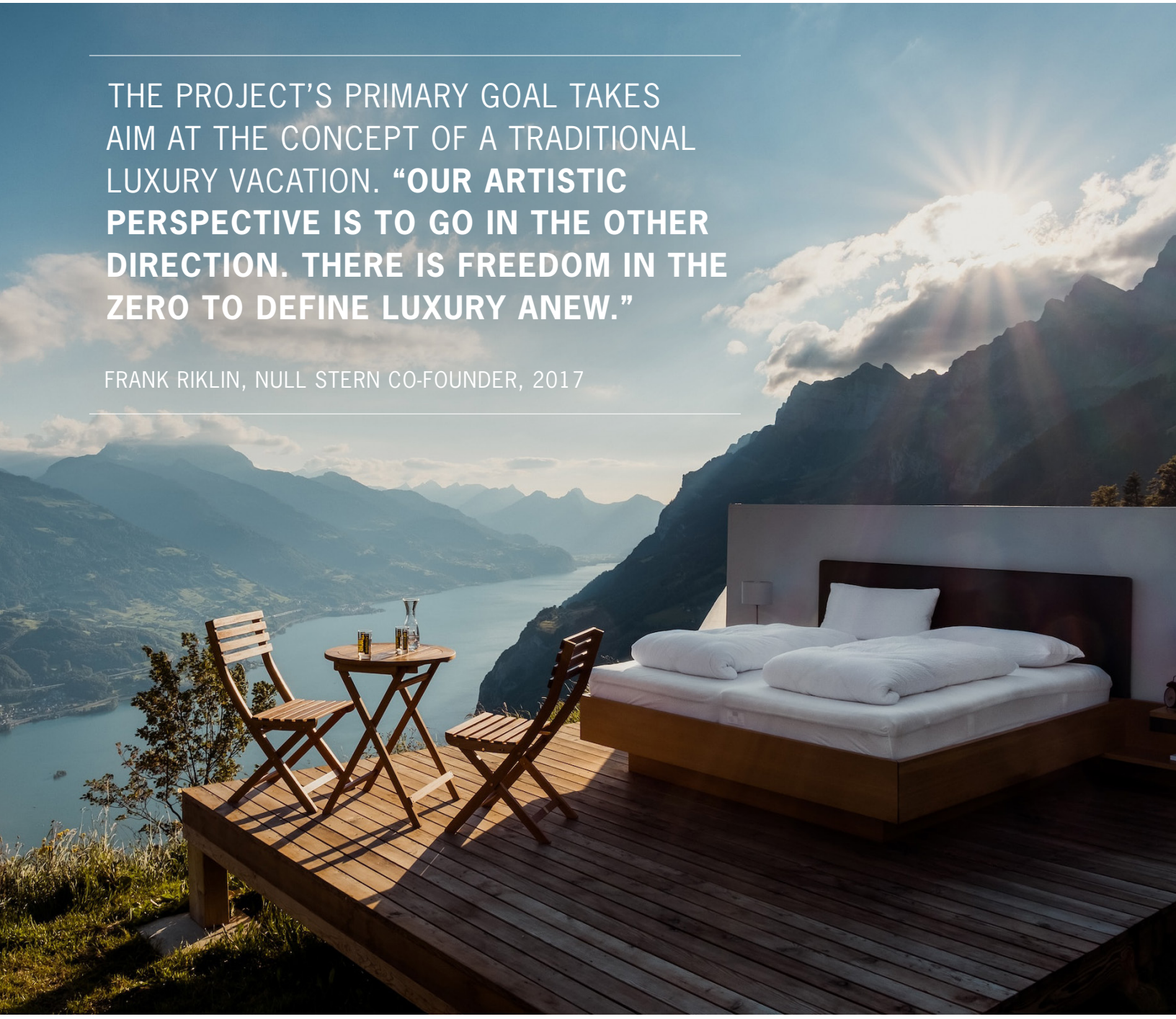


FIGURE 6.2. Prospect, risk and nature immersion at Null Stern ("The Zero Star") open-air, art installation-cum-hotel in Walensee, Switzerland. While evidently a jab at luxury hotel business practices, by June the bespoke experience was nearly sold out for its 2017 season. Source: TheManual.com by Mike Richard, June 16, 2017. Photo by Patrick Robert Doyle on Unsplash



FIGURE 6.3. Jungle and ocean views from hillside retreat at Atremaru Resort in Palawan, Philippines. Each chalet puts sleeping and bathing areas downstairs and the arrival, dining and living spaces upstairs. Prospect–Refuge and local raw materials are integrated with sustainable construction and rainwater management strategy, and help to distinguish the resort from its competitors around the island. Courtesy Catherine O. Ryan

This approximate price premium for nature views is also confirmed by a study of hotels in Zurich, Switzerland. In one of the hotels, rooms with wide open views to the city and Lake Zürich, with the Alps in the distance, booked for between 12% and 30% higher than rooms with a view of only trees (Lange & Schaeffer, 2001). The rooms with the distant city, lake and mountain view also had occupancy rates averaging close to 100%, a contrast to the hotel's average occupancy of 80%.

INDOOR VEGETATION

But not all rooms can have a nice view. A connection to nature can also be abstracted to be utilized indoors, such as with vegetated vignettes. Participants viewing lobby designs that included plants showed more positive emotions and satisfaction, which then had a significant impact on participants' booking intentions (Nanu et al., 2020). Some research has also pointed to a desire and subsequent price premium for biophilic design indoors. A survey of Gen Y hotel-goers conducted by Orbitz in 2019 found that 61% felt plants boosted their mood and their perception of their health on the go; approximately 50% would be more likely to "book a hotel that features photos of plants in rooms"; and 24% would be willing to "spend $50 to $100 more for a plant-filled [guest] room" (Berg, 2019). Encouraged by these results, Orbitz partnered with Garfield Park Conservatory and The Kimpton Gray in Chicago to offer 10 plant-filled pop-up guest rooms (see Kimpton Gray case study for more information).

FINANCIAL TRANSLATION

A direct impact on economic performance may be quantifiable when factoring in that references to local habitat or culture can be used as predictors of increased ADR and RevPAR (Zemke, Raab & Wu, 2018), and that views to nature (Browning et al., 2016; Lange & Schaeffer, 2001) and indoor vegetation (Berg, 2019) can be used as predictors of increased room rates. For the 67-key hotel in Zurich, the impact of the view on the hotel's profits was an estimated increase of $456,980 per year (Lange & Schaeffer, 2001).



FIGURE 6.4. Window planter at 1 Hotel Central Park in New York City, improves view quality and potential hedonic value. Photo courtesy Bill Browning

GUEST PERCEPTION: LOBBIES & AMENITIES

More than a first impression, the hotel lobby is the place where a great many guest needs are met. With a renewed appreciation for common spaces, the purpose and design of the lobby have transformed into a "home away from home" trend, becoming more welcoming and less austere (Frochot & Kreziak, 2019). Lobby spaces are more like living rooms, offering "private-public" areas, which resonates with travelers, and with Gen Y in particular (Sterkenberg, 2017).

The lobby is being reimagined as a space where travelers can spend a whole day in various private and public spaces (Durst, 2018). The lobby experience can also be a top reason why travelers choose a hotel over the fast-growing market of Airbnb or VRBO accommodations (Nagy, 2018). Common spaces have thus received an increasing proportion of renovation capital in recent years (Manley, 2018).

Lobbies also play a leading role in hotel economics when incorporating ancillary services and experiences. Since the economic impact of each guest is dependent upon both the room price and how their time is spent, a fully booked hotel can increase revenue when greater dwell time is achieved in communal spaces with revenue-generating amenities. To understand the overall economic impact of a guest—and rationale for biophilic common spaces—hoteliers track total revenue per available room (TRevPAR), often valued on a per-occupied-room basis. TRevPAR accounts for additional revenue from operated amenities—food and beverage, spas, conferences, golfing, banqueting—and paints a far more comprehensive picture of a hotel's economic performance. In a particularly notable example, Accor's lifestyle hotels are estimated to earn more than 50% of their revenue from local traffic taking advantage of such amenities (Sperance, 2021). There is some indication that this shift in opportunity value is occurring across multiple hotel market segments, despite the COVID-19 pandemic, with resorts benefiting the most (e.g., Mandelbaum, 2020).

BIOPHILIA RESEARCH FINDINGS

Biophilic design has been shown to promote increased dwell time, environmental satisfaction, and engagement in hotel and retail servicescapes. A guest's mood has a significant impact on a number of their experiences:

- Perceived quality (Tifferet & Vilnai-Yavetz, 2016; in Purani & Kumar, 2018),
- Satisfaction (Nanu et al., 2020),
- Evaluations (Gardner, 1985; in Purani & Kumar, 2018), and
- Booking or rebooking intentions (Nanu et al., 2020).

Mental fatigue also has a measurable impact on satisfaction, experience, and behavioral intentions (Hartig et al., 2003).

DWELL TIME

In the Human Spaces 2.0 report on biophilic design in hospitality, lobby utilization was assessed across six midtown Manhattan hotels, half with biophilic lobbies, half with conventional lobbies. In the biophilic lobbies, 36% of lobby occupants were identified as either actively or passively using the lobby space, as compared to 25% in the conventional lobbies (Browning et. al, 2016).

A disposition to dwell in biophilic lobbies was shown again in a scenario-based experiment, in which Seung Hyun Lee (2019) assessed emotional response, quality perceptions, and behavioral intentions for three different biophilic features (plants, water features, and natural light) compared to a control hotel environment. Analysis revealed significantly higher levels of pleasure and arousal, higher perceived quality, and more favorable attitudes for each of the three biophilic features. Furthermore, higher enjoyment and greater willingness to spend more time and money was reported for the biophilic lobbies (Lee, 2019).

GUEST EXPERIENCE AND SATISFACTION

Guest experience has risen to the top of the list as Gen Y travelers make up an increasing share of business. Among those travelers, 72% say they would rather spend money on experiences than material goods (Gherini, 2018); more than half want to learn from communities they visit, and 45% see travel as a means to get connected to other cultures (Barkley Inc & FutureCast, 2016).

From an economic standpoint, evidence of improved guest experience may manifest as loyalty (repeat business), positive reviews, social media posts, and word-of-mouth buzz. Travelers are increasingly turning to user-generated content to choose a hospitality destination: “87% of millennials use Facebook for travel inspiration; more than 50% use Twitter or Pinterest” (Barkley Inc & FutureCast, 2016). Thus, a place or experience worthy of a social media post can market itself.

Guest satisfaction with the physical environment has a strong positive impact on intentions to return (Worsfold et al., 2016). Repeat guests are incredibly valuable for hotels. When profiled in the 1990s, the highly biophilic Inn of the Anasazi in Santa Fe, NM, was running at 83% annual occupancy, a third of the guests being return customers (Rocky Mountain Institute et al., 1998).

GUEST REVIEWS

The content of customer reviews has been shown to relate directly with hotel design. In one example, referencing TripAdvisor reviews as the basis of analysis, guests reviews for hotels with conventional lobbies were found to most often dwell on maintenance and service related topics, while guests of biophilic hotels most often dwelled on the design and decor related topics (Browning et al., 2016). Furthermore, guest reviews for the biophilic hotels mentioned "experience" twice as often as those for the conventional hotels.

For mental restoration, biophilic servicescapes have resulted in outcomes superior to conventionally designed servicescapes. Services provided in spaces enabled by the incorporation of biophilic elements (e.g., vegetation, natural finishes, daylight) have been shown to result in far better evaluations for at least four experiential dimensions—fascination, feelings of being "away", pleasure, and excitement—all of which are key to restoration (Purani & Kumar, 2018).

FINANCIAL TRANSLATION

By developing services and programming in shared spaces that are biophilic in character (i.e., biophilic servicescapes) so as to encourage dwell time, hotels may benefit from an increase in spending behaviors that directly boost hotel revenue. The idea that increased dwell time leads to increased sales is deeply embedded in retail design and research. Conducting more research on dwell time and purchasing behavior in hotel lobbies and amenity spaces would establish a stronger basis for financial evaluation.

D.I.Y. TIPS

It pays to make the hotel experience one to which guests are attracted and stay loyal. Biophilic design can be used in many ways to help do this; here are a few low-barrier entry points.

- Transform underutilized spaces into nooks in which guest can take restorative breaks
- Create unique photogenic 'Instagrammable' opportunities to capture the biophilic qualities of a space and communicate the role nature has in the brand identity or ethos—free marketing by influencers.
- Introduce vegetation and multi-sensory experiences at thresholds and transition spaces to buffer overtly stimulating experiences (urban streets)
- Upgrade a few guest rooms with biophilic experiences to distinguish them from other rooms and market them at a higher rate category.
- For guest rooms with poor view quality, redirect attention to an interior "preferred view"—the wall, bed or cozy nook. Decorative ambient lighting, terraria, or nature-inspired wall treatments can help create that preferred view.

FROM THEORY TO PRACTICE

IN HOSPITALITY

At the nexus of experience, well-being, and environmental satisfaction, biophilic design has garnered increasing attention by hospitality designers and operators alike. In November 2017, Hotel Management highlighted biophilic design as one of the top three "biggest trends hotel designers will need to keep in mind" for 2018 (Fox, 2017), and that trend has continued (Potter, 2021). Brian Vickery, Senior Director, Design and Construction at Four Seasons Hotels and Resorts, is quoted as having said that "...there's a movement toward what people want… As a brand, the expectations of guests are leaning toward health and wellness. That means creating biophilic, sustainable, and wellness-focused spaces isn't just a sound investment. It's doing the right thing" (Riley, 2019).

Recent trends have included embedding biophilic design parameters into brand standards or, for franchised hotels, identifying design tactics to overlay existing brand standards to either enable more place-based experiences or to overcome design challenges unique to the property.

Both large- and small-budget interventions are on the rise in hotels globally. The movement toward making guest rooms and amenities photogenic and Instagram-ready has been largely focused on adding vegetation, nature-inspired wall or textile patterns, natural materials, and cozy window seats. When executed with intention and quality, these types of small-budget interventions can have measurable impacts. With the uptick in staycation and business leisure or 'bleisure' guest visits (since the COVID-19 pandemic, in particular) hospitality groups like Marriott, Hyatt, and Hilton have each embraced the concept of extended stay packages. Staycation and bleisure guest needs (e.g., relaxation, restoration, work focus) present opportunities for hotels to offer health and wellness experiences grounded in biophilia. One such emerging practice has been to invest in the creation of an immersive biophilic experience for a few guest rooms—rather than spreading a small budget across the whole hotel—as a way to trial design strategies, offer unique experiences, attract new and return guests, and test the market. A successful intervention may lead to permanent installations and rolling or seasonal offerings.

More extensive interventions have been grounded in establishing meaningful connections with the community by addressing both general environmental, social, and governance (ESG) priorities and targeted, critical social and environmental issues. Trending practice is to showcase the hotel design and operational practices to facilitate discussions on sustainability and resilience with a broader audience. Integrating biophilic design with other building systems and strategies has been on the rise as a cost-effective solution to multiple issues that essentially become so completely integrated that any one strategy cannot be decoupled (i.e., value-engineered out) without upending the whole design. Hotel Magdalena in Austin, Texas is one such example. Designed by Lake|Flato and Ten Eyck Landscape Architects, Hotel Magdalena is the first mass-timber, boutique hotel constructed in North America; the project's strategies for biophilic design (natural grain materials, prospect-refuge, daylighting, views) and reduced embodied carbon (mass timber) are deeply intertwined.



FIGURE 6.5. Complexity and order of aged and highly textured wood, bamboo, stone and earth interiors contribute to a welcoming and restorative atmosphere at Muji Hotels in Japan and China. Photo by Jack Zhang on Unsplash

BIOPHILIC HOSPITALITY CASE STUDY

BOUTIQUE: SIX SENSES DOURO VALLEY HOTEL & SPA

BIOPHILIC PATTERNS: MULTI-SENSORY CONNECTION WITH NATURE

Nestled in UNESCO World Heritage-listed Douro Valley, Portugal, the Six Senses Douro Valley Resort and Spa sits on 19 acres—including a 19th-century manor house, a preserved woodland, and a donkey sanctuary—surrounded by rolling hills and wine vineyards overlooking the River Douro. Essential to the Six Senses Douro Valley experience is having stunning views out to the historic wine country.

Of the resort's 60 guest accommodations, four shared the inconvenient trait of having an unmarketable view of a barren rooftop, and were consequently offered at a lower, "Standard" price bracket from other rooms. Despite being available at a more economical price point, these rooms were not booked as frequently as "Deluxe" rooms with similar interior design and layout. To improve the economic return of these four rooms, Clodagh Design teamed up with Italian landscape architect Topiaris to incorporate lushly landscaped private terraces in hopes of transforming the guest experience of each room.

In the renovation, the adjacent rooftop was transformed, including the removal of an underutilized skylight well, into a terrace accessible to the guest rooms. The design team partitioned the area into four private terraces linked to a lush common space. No changes were made to the guest room interiors. By offering an alternative but equally biophilic experience, the four accommodations now have occupancy rates comparable to those with the valley views.

This exterior transformation enabled the guest rooms to be upgraded from the Standard to the Deluxe price bracket, boosting RevPAR and yielding a healthy return on investment. In 2017, Six Senses Douro Valley was recognized as a Best of the Best Virtuoso Winner for 'Best Achievement in Design'.







Content courtesy Clodagh Design; Images courtesy Topiaris (top, bottom) and Clodagh Design (middle)

BIOPHILIC HOSPITALITY CASE STUDY

BRAND–FRANCHISE: WESTIN HOTELS

BIOPHILIC PATTERNS: BIOMORPHIC FORMS, DYNAMIC & DIFFUSE LIGHT, COMPLEXITY, MATERIAL CONNECTION

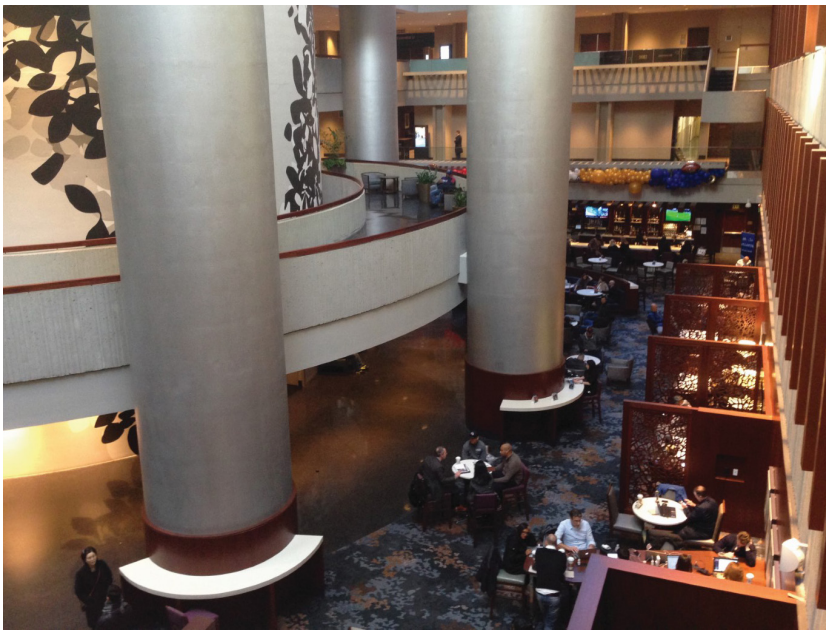
At the brand level, the design team at Marriott extended the idea of Westin's highly popular "Heavenly Bed" to apply to the entire guest room. The new brand experience would focus on wellness, with biophilic design explicitly part of the design strategy for the guest rooms. Two interventions addressed lighting, including an overhead perforated panel in the guest room entryway and perforated sconces by the bed headboard. The diffused light splashes fractal light patterns on the walls—much like the dappled light in a forest—and is intended to help lower stress the moment a guest opens the door. While it would be hard to quantify how a lighting installation could increase the average daily rate (ADR) for the room, Westin's branding team felt that the advertising value of guests posting a picture of this feature on social media would be greater than the cost of the installation at any of their franchised hotels.

At the franchise level, the refresh of the atrium at Westin Peachtree Plaza in downtown Atlanta aimed to transform an underutilized but dramatic multi-story volume into a convivial gathering space. Three main biophilic interventions were incorporated:

- Partitions with a biophilic perforation pattern were spaced along the below-grade atrium perimeter and near the bar to make partial refuge space for small-group gatherings with longer dwell times;
- Supergraphics of magnolia flowers were affixed to the concrete core wall, adding dimension and intrigue to the volume; and
- Green walls were installed at reception desks that primarily benefit reception staff yet offer a more welcoming arrival experience for guests.

The refresh also retained upper-level experiences, most notable of which are perceptions of prospect and risk, which encourage exploration, help with wayfinding, and lure patrons down to a variety of seating options to encourage dwell time and purchases from the bar.





Content courtesy David Kepron. Photos: Westin Gen5 prototype guest room (left), courtesy of Marriott International; Westin Peachtree Plaza in Atlanta, GA. (right), courtesy Bill Browning.

BIOPHILIC HOSPITALITY CASE STUDY

POP-UP: KIMPTON GRAY CHICAGO

BIOPHILIC PATTERNS: VISUAL CONNECTION WITH NATURE, NATURAL ANALOGUES

Between May 30 and June 6 in 2019, online booking company Orbitz conducted a survey of 1,028 U.S. travelers, ages 25–44, revealing that nearly two-thirds wanted plants in their hotel rooms, nearly half would be more likely to book a guest room that features photos of plants, and a quarter would be willing to pay more for a vegetated guest room (Berg, 2019).

These findings led to a three-day pop-up experiment (October 18–20, 2019) at the Kimpton Gray in Chicago. Working with the Garfield Park Conservancy (GPC), Orbitz installed plants, bedding, and amenity kits representing five different planting themes (The Fern Room, Palm House, Sugar from the Sun, The Desert House, and Aroid House) into 10 guest rooms at Kimpton Gray. This approach to biophilic design emphasized the "preferred" interior view, rather than the street view—an especially effective strategy when marketable city or nature views are not available. The hotel also adapted the lobby into what Dina Fenili, Kimpton Gray's director of sales and marketing, referred to as an "open-air greenhouse" with diverse species, including herbs. The program for the lobby also shifted to encourage dwell time and guest interaction, including a nightly social hour with herb-infused custom cocktails (McMillin, 2019).

Guest rooms were priced at "Deluxe" rates from $368 to $563 per night—a slight premium over the hotel's "Standard" rate—and were bookable exclusively on Orbitz.com. While the short-term offering limited the number of guests able to experience the planted rooms and thus restricted potential revenue, it did minimize long-term maintenance requirements while allowing the hotel to promote GPC's mission to "inspire, educate and provoke exploration" (Berg, 2019) and, whether intentional or not, to boost media attention and test the market. According to Orbitz, all 10 rooms were sold out (Orbitz, n.d.).





The "Sugar from the Sun" (above) and "Fern House" guest rooms at Kimpton Gray Chicago featured tropical species, while the "Desert House" guest room (below) was adorned with a variety of cacti. Content courtesy Orbitz.com and David McMillin for PCMA.org; Photos by Marcin Cymmer / The Kimpton Gray

FUTURE DIRECTIONS
FOR RESEARCH & REPORTING

With the U.S. alone having 4.9 million hotels (from motels to 5-star hotels) and 9 million guest rooms—collectively generating more than $194 billion of revenue annually (Condor Ferries, 2022)—the opportunities for experiential interventions seem endless.

Research has primarily focused on experiences of:

- Guest room views to outdoor nature
- Indoor vegetation in lobbies and guest rooms

Particularly when related to:

- Pricing
- Customer behaviors (e.g., dwell time) associated with sales

Moving forward, an understanding of the relationship between biophilia and hospitality outcomes could be expanded to several additional areas of focus:

- Relationships between biophilic hotel lobbies and amenities with service effectiveness, TRevPAR, room sales, return guests, or related metrics.
- Cost benefit of biophilic interventions in guest rooms compared to common amenities.
- Non-vegetal biophilic design interventions such as natural materials, water, or refuge.
- Staff retention: With 39% of front-of-house staff departures being within the first 90 days of employment (Condor Ferries, 2022), is there a meaningful role for a biophilic workplace experience in hospitality?
- Case studies that report on economic and behavioral outcomes, not just the biophilic design or experience offered.



7. COMMUNITY

Much like ecosystems, communities are complex adaptive systems in which innumerable relationships and interactions lead to emergent behaviors or outcomes—ones that would not manifest among citizens or departments independently—that cannot always be explained or predicted. This net-positive emergence (the whole being greater than its parts) is at the heart of the evolution of society and why individuals can never hope to achieve, in isolation, what is possible in a cooperative community. This perspective can be particularly useful when assessing the benefits of applying biophilic design to urban planning, community development, and public health and well-being and, more critically, in approaching broad issues such as a pandemic or climate change.

A community embodies both a physical place and a network of social and economic relationships. For local governments, the goal is to foster and sustain a high quality of life for its residents by way of policy, regulation, and efficient spending. The intent of community investment is

KEY TAKEAWAYS

- Access to green space and tree canopy has a strong correlation to better public health outcomes regardless of income levels.
- Street trees and neighborhood parks can increase prosocial behaviors and decrease crime.
- Street trees, community gardens and parks can increase property values, but may increase displacement risk if not planned properly.

FIGURE 7.1. Edmonton, Canada has been a member of the Biophilic Cities Network since 2016 © Hotels.com

TABLE 1.7. BIOPHILIA IMPACTS & FINANCIAL INDICATORS FOR COMMUNITY

SECTOR	HEALTH & WELL-BEING INDICATORS	FINANCIAL INDICATORS	
		DIRECT	INDIRECT
Community	perception of safety, crime rate; overall public health	tourism; violent crime rate	investment attraction, migration, urban patriotism, real estate value, tax base; climate change adaptability, resilience, equity; incarceration rate

to create value for all members of the community in a way that outweighs investment costs. Many public sector services inform or influence the feasibility and impact of biophilic design investments in a community. Municipal departments of Public Health, Parks and Recreation, Economic Development, Buildings and Ordinances, Transportation, and Emergency Services each have a hand in aligning, manifesting and upholding supportive policies, physical infrastructure, and program oriented strategies.

A community's physical characteristics affect the mental well-being, health, and behaviors of its population(s), which often differ from one community to another. For instance, residents of urban settings have a higher prevalence of psychiatric disorders—in particular, mood and anxiety disorders—than their counterparts in rural settings (e.g., Peen et al., 2010). As human settlements continue to densify—68% of the world population is projected to reside in cities by 2050 (United Nations, 2018)—interactions with the built environment will increase, as will the importance of designing communities that actively support happy and healthy people.

Great strides in community investment have come from recognizing how people and places influence one another. Community access to nature, whether in the form of parks, street trees, or community gardens, supports many community development goals, including greater physical activity and health, improved social cohesion, prosocial and sustainable decision-making, and more desirable places to live. Conversely, when people are deprived of access to nature and its many benefits, there are economic consequences—specifically for health and its associated costs.

This chapter looks at available research on biophilic design, particularly vegetation or "greenery" (as the research often frames it), as it relates to public health and to community cohesion, prosocial behavior and crime reduction, as well as to real estate value and tourism across a variety of financial indicators.

PUBLIC HEALTH

Healthcare expenses are a significant burden on U.S. citizens. In 2017, the average American spent $4,928 per year, or 8.2% of their total annual expenses on health care (BLS, 2018). The share of a family's income going to healthcare varies depending on income level and family health status. In an analysis led by non-profit organizations Peterson Center on Healthcare and Kaiser Family Foundation, families making less than two times (2×)



FIGURE 7.2. The community biological wastewater treatment at Serenbe in Chattahoochee Hills, Georgia, appears to residents and passersby as a field among forests. © Catherine O. Ryan

the poverty level spent 14% of their income on health costs, compared to families making four or more times (4×) the poverty level, who spent 4.5% of their income on health costs (Claxton, Sawyer & Cox, 2019). The same study found an average 51.9% increase in spending for those with a family member in fair or poor health compared to families with no member in fair or poor health (Claxton, Sawyer & Cox, 2019). Thus, alleviating healthcare expenses not only reduces the overall economic burden of citizens but may also more significantly benefit those of lower socioeconomic standing.

Communities can invest in health promotion and disease prevention as a means of addressing income inequality and community economic drain. The potential return on such investment is perhaps nowhere higher than in the United States; the U.S. has the highest chronic disease burden of any high-income country (Tikkanen & Melinda, 2020), with 60% of Americans having at least one chronic disease (CDC, 2021). Furthermore, 86% of all U.S. healthcare expenses go to treating someone with at least one chronic disease (Gerteis et al., 2014).

Many of the most prevalent chronic diseases, including obesity, Type II diabetes, high blood pressure, heart disease, and certain cancers, stem from an increasingly sedentary, indoor lifestyle (John Hopkins Medicine, n.d.). According to the Centers for Disease Control and Prevention (2016), only 22.7% of American adults meet the exercise requirements set by the Federal 2008 Physical Activity Guidelines. The physical characteristics of a community, including the presence and accessibility of nature, affect decisions to engage in physical activity for commuting and during leisure time. For example, non-existent or poorly maintained parks, sidewalks, and sports/recreation facilities—as well as poor air quality, dense traffic, and crime—discourage participation in outdoor physical activity for highly urbanized communities (World Health Organization, 2008). Equitable access to green space could help improve these numbers.

BIOPHILIA RESEARCH FINDINGS

PHYSICAL ACTIVITY

Proximity to green space and tree density is correlated with increased outdoor physical activity that ultimately impacts individual and public health metrics and costs. Researchers have found that people who use public open spaces are three times (3×) more likely to meet recommended physical activity levels (e.g., Giles-Corti et al., 2005). People are also more likely to take walking trips when the route is believed to include more natural features while, in contrast, people are more likely to overestimate distance within neighborhoods with less greenery, which decreases the likelihood of taking walking trips (Tilt, Unfried & Roca, 2007).

PERCEPTIONS OF HEALTH

Community greenery also correlates with subjective perceptions of health (e.g., Maas et al., 2006). Using satellite imagery and city planting data, Kardan and colleagues (2015) approximated tree density across Toronto



HAVING 10 MORE TREES IN A CITY BLOCK CAN INCREASE HEALTH PERCEPTION TO THE SAME DEGREE AS $10,000 MORE IN ANNUAL INCOME OR AS BEING 7 YEARS YOUNGER.

KARDAN ET AL., 2015

FIGURE 7.3. Toronto, Canada, has been a Biophilic Cities Partner since 2020. The city has implemented four bylaws that address urban biophilia, as well as several supporting initiatives. Photo courtesy Biophilic Cities Network

and compared that data with survey responses from participants around the city. Results revealed that people living in locations with higher tree density had significantly higher health perception and significantly fewer cardio-metabolic conditions (e.g., cardiovascular diseases, hypertension). From this study, researchers concluded that, even when controlling for socio-economic and demographic factors, having 10 more trees in a city block can increase self-reported perception of health to the same degree as $10,000 more in annual income, or as being seven years younger.

The outcomes of the Toronto study were similar to those from the Netherlands where the survey of 10,000 people, independent of income or other demographics, indicated a very strong correlation between self-reported healthiness and nearby green space (deVries et al., 2003). A long term goal for the city of Barcelona is that every citizen will be able to see at least three trees from their windows, have 30% tree canopy coverage in their neighborhood, and be no more than 300 meters from green space. This is referred to as the 3–30–300 green space rule. While only a small percentage of the Barcelona population currently has that level of access to green space, a study indicated that residents have better mental health outcomes and take fewer sedatives and antidepressants (Nieuwenhuijsen et al., 2022).

CHRONIC DISEASE

Given increased physical activity and self-reported health, it is not surprising that residents of greener (vegetated) areas within a community show better health outcomes. This effect is most directly evident in the research of Brown and colleagues (2016), who found that areas ranking high in their vegetation index (more densely vegetated) were associated with fewer cases of chronic disease. More specifically, areas that were one standard deviation above the average vegetative index score had 49 fewer cases of chronic disease per 1000 residents as compared to areas that scored one standard deviation below the average vegetative index score (Brown et al., 2016). It should be noted that some of this may be due to an increased likelihood that more attractive outdoor spaces encourage more physical activities.

FINANCIAL TRANSLATION

The significant community-borne costs of treating chronic disease further support the need to prevent chronic disease. Expanding on the findings of Brown and colleagues (2016), a community of 100,000 with high greenness (one standard deviation above the mean) as compared to a similar community with low greenness (one standard deviation below the mean) is estimated to have 4,900 fewer cases of chronic disease. Given Kaiser Family Foundation's estimate of a $2,705 per year difference in healthcare costs between a healthy individual and a person in poor health (Claxton, Sawyer & Cox, 2019), high greenness could potentially save as much as $13,250,000 across a community of this size (see Appendix B1).

URBAN PATRIOTISM

In design, we challenge ourselves by asking why a design decision is important or worth pursuing. In doing so, we must also consider why people would want to live in a particular building, neighborhood, or city. A Public First report defines urban patriotism as "an emotional, visceral attachment" to a city that is core to a population's identity (Public First, 2021).

For communities aiming to attract investment and to retain an optimal population level and sustainable tax base, biophilic planning and design —with its emphasis on placemaking through establishing emotional connections with nature—may be a suitable strategy for boosting a sense of urban patriotism.

COMMUNITY COHESION, PROSOCIAL BEHAVIOR & CRIME REDUCTION

Community is about interactions, cooperation, democratic decision-making, collective action, and mutual support. This web of social interaction also forms the basis of an economy. In economic terms, this is often referred to as social capital, which has many definitions, but can be summed up as being the networks of relationships among people in a particular society that enable capacity to function effectively.

Social capital, as an invaluable community asset, rests upon the psychological well-being and social dynamics of residents. When people feel happy, are trusting, have a sense of belonging, and feel heard, they are more cooperative, productive, and engaged in community decision-making processes, and may develop a stronger attachment to place (see sidebar on Urban Patriotism). Conversely, when communities see greater social fracturing, crime, and psychological deterioration, they are more economically burdened. Crime, for example, imparts direct community-borne costs in the form of court services, incarceration costs, medical expenses, and property damage, as well as indirect costs in the form of lost worker productivity and trust. It is estimated that every case of murder costs $5 million and every serious assault costs $55,000, each paid for by the victim(s) and local tax-payers (Cohen & Piquero, 2009). In Chicago, the aggregate cost of crime has been estimated at $8.29 billion per year (Heaton, 2010) and, in 2022, the Chicago and Cook County budget just for policing, incarceration, and the courts, was $4.1 billion (Grimm, 2022).

BIOPHILIA RESEARCH FINDINGS

A number of studies have shown that vegetation and nature-inspired design elements in community gathering spaces can encourage use of those spaces, as well as better social capital development and positive behavioral outcomes among community members (Kuo et al., 1998; Zelenski, Doplo & Capaldi, 2015).

SOCIAL COHESION, EMPATHY AND COOPERATION

Common spaces with more vegetation have been shown to increase utilization and subsequently encourage greater social ties in an area. Residents with access to well-planted common spaces are shown to have more social activities, host more visitors, know more neighbors, and feel a stronger sense of belonging and safety (Kuo et al., 1998).

The social vitality of communities can also be measured by metrics for prosocial behavior. Research indicates that those who report a greater connectedness to nature likely to:

- Report feeling greater empathy toward others (Fido & Richardson, 2019; Metz, 2017);
- Act more cooperatively (Zelenski, Doplo & Capaldi, 2015);



FIGURE 7.4. Challenged by the fire chief to design Marion Fire Station No. 1 to be a national benchmark for how biophilic design can reduce PTSD in fire fighters, OPN Architects used natural and biomorphic patterns and materials, daylight, views, access to the outdoors, and circadian rhythm-based lighting, to optimize the positive effect on the firefighters' well-being, including stress reduction, increased awareness, and improved cognitive ability. This city government building in Marion, Iowa, has been the recipient of several awards, including the 2023 Stephen Kellert Biophilic Design Award. Photo credit to Cameron Campbell, Integrated Studios

- Show more environmentally sustainable behavior (Zelenski, Doplo & Capaldi, 2015);
- Show a greater willingness to give money to others (Weinstein et al., 2009); and
- Support social goals (Weinstein et al., 2009).

While the tendency to future discount (i.e., to delay satisfaction in favor of a better reward later) varies significantly across populations, it too can be influenced by environmental factors. For instance, exposure to natural versus urban environments has been shown to reduce a person's future discounting rate by an average of 10%–16% (Van der Wahl et al., 2013)—a behavior change that has considerable implications for the community planning process.

CRIME REDUCTION

In 2001, Frances Kuo and William Sullivan conducted two studies connecting shared green space with improved behavioral outcomes and mental well-being for Chicago's public housing residents. In the first study, extensive interviews and cognitive tests revealed that residents living in apartment buildings near more vegetated outdoor spaces demonstrated lower mental fatigue, aggression, and violence (Kuo & Sullivan, 2001a). The second study took a more quantitative approach, measuring differences in crime rates over a two-year period in the 98 apartment buildings. The researchers reported that 52% fewer felonies occurred in the buildings with nearby outdoor vegetation, and that the greener a building's surroundings were, the fewer property crimes and violent crimes reported (Kuo & Sullivan, 2001b). This relationship of vegetation to crime also held up after other key variables were factored in, such as the number of apartments per building and vacancy rates, among others.

DISPLACEMENT RISK

Differentiating metrics from goals is critical to recognizing the real benefit to a community. Increased real estate values may be a necessary metric to pay attention to but are not always objectively good for the community. Higher living expenses can price out long-time residents, particularly if the benefit of that increased value is not shared equitably. Such problems often stem from ownership structures within communities. Those who own benefit, those who rent get priced out; yet increased taxes can also pressure lower income owners to sell. Increased value in a community also translates to a greater tax base and more funds that local governments are able to divert toward rent support or a local land trust that can democratize land ownership and stabilize rent prices—particularly where there are taxes or fees levied on land that has gained in value due to public infrastructure investments. When new investment is put toward a common-pool resource, such as public green space, that value can be more evenly distributed across the community.

The Highline in New York and the Beltline in Atlanta are examples of park projects that have increased tourism and new investment but that have also led to significant gentrification. In an assessment of the Beltline, Dr. Dan Immergluck, a professor of Urban Studies at Georgia State University, argues that designating land, to a land trust or dedicated affordable housing, should be done in advance of developing a new green space (Immergluck, 2023).

Since Kuo and Sullivan's seminal studies, other researchers have cited strong inverse relationships between city greenery and crime, controlling for income levels, educational attainment, and racial and ethnic composition. In Baltimore, Maryland, researchers used geocoded crime point data to determine that areas with 10% more tree canopy were associated with an 11.8% lower crime rate for that area (Troy, Grove & O'Neil-Dunne, 2012). In New Haven, Connecticut, a 14% reduction in total crimes (including a 15% reduction in violent crimes alone) was associated with every 10% increase in tree canopy (Gilstad-Hayden et al., 2015). Given New Haven's average annual crime rate of 68.1 per 1,000 people, a 10% increase in tree canopy across the city could result in 1,239 fewer crimes each year (see Appendix B2).

New tree planting campaigns have also had measurable impacts. The direct impact of a public tree planting campaign on crime in Portland, Oregon, for instance, revealed that for every 100 street trees newly planted in a neighborhood, 24 fewer violent crimes were committed in that neighborhood in the following year (Burley, 2018). While crime rates may fluctuate year to year, 24 fewer crimes per 100 trees is still a significant reduction. Furthermore, several studies have found that street vegetation was more impactful in economically disadvantaged areas and for reducing violent crimes specifically (e.g., Gilstad-Hayden et al., 2015; Burley, 2018).

FINANCIAL TRANSLATION

Crime reduction can be understood in terms of decreased citywide spending. The average crime-rate reduction due to increased tree coverage across aforementioned studies was 13% for every 10% increase in tree canopy density. To put that number in context, The Center for American Progress found that a 10% reduction in violent crime in Chicago would reduce direct costs to victims by $43 million, reduce intangible



FIGURE 7.5. 11W, a mixed-use highrise in downtown Portland, OR, was designed by ZGF Architects to optimize connections with nature, particularly in its amenity spaces. Multifamily housing is a microcosm of community activity. Common space and amenities are often targeted for biophilic interventions, benefiting all tenants who use them. Photo courtesy Catherine O. Ryan

costs to victims by $420 million, save the local government $24 million each year, and yield $2.2 billion in increased real estate value (Shapiro & Hassett, 2012)—savings and benefits that could potentially be achieved through increasing the urban tree canopy by less than 10%.

REAL ESTATE VALUES & TOURISM

Once more basic goals of health, safety and social cohesion are met, a community can focus on higher-order needs of residents, such as happiness, pleasure, and enjoyment. Whether through beauty, amenities, attractions, or work opportunities, the desirability of a community affects its economic vitality. Location desirability can impact prospects of new transplants, tourism, and human capital retention—the likelihood that young adults remain to live, work, and invest in the community.

The value an individual places on the pleasure derived from an experience, place, or product is referred to as the hedonic value. The benefit to the local government of investing in the enjoyment and desirability of a community, increasing hedonic value, comes from increased tax revenue from higher real estate prices, retail and hospitality utilization, and business development. In these terms, one can estimate the hedonic value of a community feature by analyzing its impact on economic transactions. However, while increased real estate values may be a target for some civic projects, such an outcome is not always objectively good for all residents or for the community's social fabric when increased property values lead to increased risk of displacement (see sidebar on Displacement Risk).

BIOPHILIA RESEARCH FINDINGS

REAL ESTATE PREMIUMS

It has long been established that greenery, especially in dense urban settings, increases the desirability and subsequent value of real estate (e.g., Crompton, 2001; Correll, Lillydahl & Singell, 1978; Morales, Boyce & Favretti, 1976). In 2010, a literature review on the direct economic impact of urban greenery, conducted by Kathleen Wolf at the University of Washington, revealed notable trends in impact on real estate values. To summarize Wolf's findings, well-forested properties and homes that are near street trees sell for approximately 7% more than homes devoid of trees; homes adjacent to naturalistic parks are typically valued 8%–20% higher; and homes with views to forested open space or parks are valued approximately 5%–8% higher than those without views (Wolf, 2010).

While real estate premiums are almost expected among properties in close proximity to large, formal parks, they are also found around small greening improvements in otherwise nature-devoid urban locations. This approach has come to be known as biophilic urban acupuncture. Perhaps the most common example of urban acupuncture is the community garden.



FIGURES 7.6. Tanner Springs is a 1-acre park in Portland Oregon, designed by Studio Drieseitl with Greenworks in 2010. The project transformed the neighborhood and has become a destination both for locals and for out-of-town visitors. Beyond the obvious presence of water and vegetation, what makes the park biophilic is the variety of spaces offering experiences of prospect, refuge conditions, and social gathering, as well as active and passive engagement with nature and wildlife. Photo courtesy Greenworks

Often transforming vacant and degraded plots, these public spaces have marked impacts on neighborhood real estate value. Voicu and Been (2008) measured the value added by community gardens across New York City. Focusing on properties within a 1,000-foot radius of a community garden, they calculated increased tax revenue from real estate sale premiums, along with cost to construct and operate a community garden across 20 years. According to their calculations, each community garden realized a net tax benefit of $512,000 for surrounding real estate over 20 years. In aggregate, the City's estimated present value of net tax benefits over 20 years was found to be $325 million (Voicu & Been, 2008).

TOURISM

Evident by the ubiquity of greenery in city promotional material, urban greenery provides the appeal cities need to attract tourists. For many, a vacation is not complete without a visit to the local park or nature preserve; and, for some, those destinations are the primary motive for the visit. Urban ecotourism describes a growing trend of tourists now seeking natural oases within large cities. In a study of tourists of Savannah, Georgia, 74.1% of respondents had visited a park, garden or square; researchers found that urban forests are the primary motive behind 54.5% of tourist visits to the city; and urban forests correlated strongly with



FIGURE 7.7. In Brooklyn, New York, Cornell University and Green-Wood Cemetery and Arboretum collaborate on impacts of revising conventional lawn mowing practices for recalibrating environmental, ecological and aesthetic goals. Most evident to visitors has been the abundance of wildflowers. Photo courtesy Catherine O. Ryan

tourists' ratings of city beauty, experience and, subsequently, both their satisfaction and destination loyalty (Deng et al., 2010).

FINANCIAL TRANSLATION

Parks and urban greenery have direct economic impact in the form of increased real estate value and subsequent tax base, and indirect impact as enticement for tourists and city transplants. The High Line, one of the most successful and recognizable urban greening initiatives, saw eight million visitors in 2019. Since opening in 2009, the area has experienced a dramatic uptick in retail sales, lodging prices, and new development. Residential real estate within one-third of a mile from the park is estimated to have increased 10% immediately following the park's opening in 2009, and associated increases to property taxes in 2010 alone were approximated to have nearly surpassed the park's construction costs (Levere, 2014).

In Portland, Oregon, street trees have been found to add an average of $8,870 to a home's sale price (Donovan & Butry, 2010); across the whole city, trees add $1.35 billion to the city's real estate value, which equates to an increase of $15.3 million in property tax revenue each year. Economists at Appleseed analyzed the value to the City of New York that Central Park provides. As just one modest facet of the park's value, they estimated that its presence contributes $26 billion in market value to properties within two tax block groups closest to the park (Appleseed Inc., 2015).

As enticement for increased tourism, parks and vegetated amenities can greatly increase local spending. In 2009, the Trust for Public Land estimated the increased tax revenue brought in from tourists visiting Balboa Park in San Diego; based on taxes from hotels, sales, and meals, tourists visiting San Diego because of the park increased the city's tax revenue by $8,578,507, and the total profit to the community as a whole was estimated at $40,033,031—35% of which was from tourists' spending (Harnik & Welle, 2009). Using contingent valuation, Majumdar can colleagues (2011) found similar results; their model suggested that in 2009, the value of urban forests to tourists in Savannah, Georgia, was $124 million annually.

D.I.Y. TIPS

While urban greening, by and large, has been shown to reduce crime and increase perceptions of safety, placement of shrubs and small trees is critical to yielding a positive outcome.

- Position shrubs and small trees in locations that do not block the line of sight. When too many understory plantings block people's line of sight, perceived safety decreases.
- Combine visual and physical connections with nature and the spatial characteristics of 'prospect' to support long distance views through public places and interstitial spaces.

FROM THEORY TO PRACTICE

IN COMMUNITIES

Conventional approaches to urban nature initiatives are often based on the economic implications of reducing gray infrastructure to combat the urban heat island effect and more effectively manage rainwater. Public health, if factored in, tends to focus on asthma, obesity rates and, more recently, food deserts. Awareness and de-stigmatization of mental health (furthered by the COVID pandemic) has led to a paradigm shift in acknowledging the prospective value of access to nature and outdoor space. This broadens the context of public health in the community and possible planning design solutions. Biophilic design can be a notable strategy for community-based initiatives, including concepts of slow streets, parklets and pop-up parks, and community gardens, as well as civic spaces, green infrastructure and other types of open space.

The last decade has seen a dramatic uptick in the use of outdoor green space as resilient infrastructure and as community amenity. Whether from grassroots community gardens, city-wide mandates requiring street trees or green roofs, or multi-billion-dollar developments, city leaders and community members alike have taken leaps to usher in biophilic agendas that support happy, healthy and economically vibrant communities.

Community gardens have been a huge success story of the last decade. In 2018, the Trust for Public Land found there to be more than 29,000 community gardens in the 100 largest US cities alone, representing a 44% increase in the six years of tracking (Trust for Public Land, 2018).

While common metrics for green space allotment are percentage of tree canopy coverage and equitable proximity to green space, the World Health Organization recommends that all city residents be within 300 meters (~1,000 ft) of a green space at least 0.5 hectares (~1.24 acres) in size (WHO, 2016). The city of Portland set a goal of 33.3% tree canopy coverage by 2035 and, as of 2015, 30.7% coverage had been reached (Portland Parks and Recreation, 2017). The program also encourages community participation, including a one-time credit, known as a “treebate,” on a resident’s utility bill for planting a tree in their residential yard (City of Portland Environmental Services, n.d.). Non-profit organizations continue to help drive community action; the Trust for Public Land developed Park Score, an index that ranks cities on their amount and equitable distribution of green space. Moreover, it identifies areas most in need of green space.

At the building scale, a number of U.S. cities have formalized ordinances and incentives for other types of green infrastructure, such as green roofs which, at a minimum, provide a visual connection to nature to anyone who can see one. Baltimore, Washington D.C., and others have tax rebates and other incentives for green roofs, while New York City, San Francisco, Portland, Toronto, and Denver require green roofs on new developments over a certain size. Investment in green roofs has clear economic benefits in terms of savings from building heating and cooling, urban heat island mitigation, and rainwater management. According to Washington State’s Department of Energy and Environment, every dollar invested in green roofs generated $2.00 in benefits (Daigneau, 2018), and this is without factoring in health benefits.

At the district/city scale, recent overhauls of city codes, lawn care ordinances and bylaws, and the popularization of citizen scientist initiatives such as ‘No Mow May’ have been largely geared toward enabling biological rainwater management, improving access to nature (particularly for recreation), and preserving/promoting biodiversity and pollinator habitats. These regulatory moves also have the potential to influence mental health, perceptions of nature, connection to place, and environmental stewardship. The economic implications of these outcomes are likely compelling, but have not been explicitly measured at the whole-community scale.

BIOPHILIC COMMUNITY CASE STUDY

REAL ESTATE RESILIENCE: SERENBE, GEORGIA

BIOPHILIC PATTERNS: MULTI-SENSORY CONNECTIONS WITH NATURE, CONNECTION WITH NATURAL SYSTEMS

The vision for the community of Serenbe, cofounded by Steve Nygren and Marie Lupo Nygren, was initially an effort to protect Georgia's rural Chattahoochee Hill country southwest of Atlanta. Recognizing the trend of psychological disorders, chronic diseases, healthcare costs, and financial hardship that accompany urbanization, the vision for the development placed 'personal well-being' as the first among several desired outcomes. This proactive and preventive approach to planning and design was grounded in the belief that people can live more fully when connected with nature—when connections between people, nature, and the arts are nourished.

Serenbe's first house was constructed in 2004. As Serenbe continued to grow, the unconventional development placed farming and extensive nature trails at the center of community health and well-being. People are drawn together through gardening, cooking, books, art, and ideas, over fences, and at the farmer's market. Homes and hamlets are connected by an Omega-shaped arterial road and a network of well-worn footpaths that make walking easier than driving and position nearly every home within two minutes of a forest. This helped to establish social cohesion through 'free-range' kids, since the open space is accessible to all, and off-street paths make it easy and safe for kids to play, explore, and traverse the community.

From these daily experiences in nature, greater empathy, prosocial behavior, decision making, and overall social cohesion have all been observed. Anecdotal evidence reveals that prescription drug use has decreased among many owners since living at Serenbe. Serenbe has won numerous awards, including the Urban Land Institute Inaugural Sustainability Award, the Atlanta Regional Commission "Development of Excellence," and the EarthCraft "Development of the Year."

The recession of 2008–10 tested Serenbe's economic resilience; 2008 became the only year in which no lots were sold. In 2010, building smaller, 900-square-foot cottages starting at $265k, helped to bring Serenbe out of the recession in 2010. When the development initially started, investors weren't interested in unconventionally planned communities, and potential buyers weren't interested in small homes, but this change in perception of responsible spending—in walkable and environmentally focused communities—is what Nygren believes got people to view Serenbe as a good investment even during a recession.

Tourism and longer-term visitors remained high and steady during the pandemic by those seeking to reconnect with nature without disconnecting from an urban lifestyle. During the pandemic, Serenbe experienced a shift in the percentage of sales attributed to nature-based activities. With restrictions on indoor gatherings, most communities experienced a reduction in in-person arts programming and events. Serenbe's walkability and outdoor community programming enabled the community to adapt to an increased demand for outdoor activities that connected residents and tourists with nature, including horseback riding, goat yoga, and the farmers' market.

The community is now home to more than 650 residents. There are shops selling flowers, bikes, books, groceries, and design services, as well as galleries, hair salons, gyms, spas, multiple restaurants, a school, and a health facility. As of 2021, the average cost of a home at Serenbe is $650k, and properties are never on the market for long—people are willing to spend more money for less square footage to ensure they get a higher-quality community living experience.



Content courtesy Serenbe; photo courtesy Serenbe Real Estate

BIOPHILIC COMMUNITY CASE STUDY

SUSTAINABILITY IN PRISONS PROJECT, WASHINGTON

BIOPHILIC PATTERNS: CONNECTION WITH NATURAL SYSTEMS, MULTI-SENSORY CONNECTION WITH NATURE

In 2018, the US Bureau of Justice Statistics reported that for 30 states between 2005 and 2014, 68% of people incarcerated in state prisons were rearrested within three years of being released (BJS, 2018). While the rates of recidivism (return to prison) can differ from state to state, as can the direct costs of retaining and providing healthcare for people who are incarcerated, the indirect costs to affected communities are measurable.

According to the Washington State Department of Corrections (DOC), the statewide average cost per resident in 2019 was $112.96 per day, or $41,230.40 per year. Cost per incarcerated person includes psychological treatment and other healthcare costs, which can amount to 20% of prisons costs. Recidivism is a common metric for measuring the impact of reduced financial, health, and social burdens of incarceration on a population or community.

Starting in 2002, Washington DOC made a strong commitment to sustainability, including participating in the nationwide Sustainability in Prisons Project (SPP). The SPP's Restorative Nature programs enable regular interaction with nature by people in prison and correctional officers and have been exhibiting notable reductions in recidivism (see Table A for biophilic programming measures).

Two signature programs of SPP are Roots of Success, an environmental literacy curriculum that's a prerequisite to participating in other programs, and Ecological Conservation Technicians, a formal education and training curriculum in natural resource management (e.g. butterfly rearing, beekeeping, prairie plant nurseries). In 2019, recidivism was analyzed for these two programs. Among the 140 Roots of Success graduates released three or more years before (on or before June 30, 2016), 30% had recidivated; and of the 61 trained Ecological Conservation Technicians released from prison, only 18% recidivated. In total, 26% of SPP participants in the data set recidivated compared to 34% for the general population. This seems to be a better result at reducing recidivism than just standard education programs (Davis, et. al, 2013).

With SPP training, these individuals are able to reenter society to meaningfully serve as environmental stewards for the benefit of community members and local businesses, while also reducing the burden on taxpayers: in 2019 alone, the SPP saved the DOC $41,230.40 for each person who did not recidivate, or roughly $659,686, and millions more since the program began in 2002. While the SPP study assessed a relatively small population, the findings are similar to studies conducted for garden interventions in other prison systems, including the Rikers Greenhouse horticultural therapy program at the Rikers Island Prison Complex in New York, which has reportedly reduced recidivism rates by 40%; and California's Insight Garden Program, at San Quentin State Prison and across the state, that reports a less than 10% recidivism rate and an estimated $40 million saved (based on $47,421 per year per inmate).



Participants in the nurseries at two of Washington's corrections centers receive education and training to grow several species of native flowering plants to support active regional restoration ecology projects. Photo courtesy Sustainability in Prisons Project (SPP) Fiscal Year 2019 Annual Report

The SPP studies and available DOC records do not make connections between the impact of the biophilic interventions and specific improvements in mental health and behavior (e.g., reduced aggression, depression, anti-social and self-destructive behaviors; demand for health care services and prescriptive medication) or associated staffing, healthcare and operational costs. Research that investigates such correlations may reveal further insights into the benefits of Restorative Nature programs for people in prison, correctional officers, their families, DOCs across the country, and the communities they serve.

TABLE A. BIOPHILIC PROGRAMMING AT WASHINGTON STATE PRISON FACILITIES

SPP PROGRAMS	PRISON	HIGHLIGHTS
Nature Imagery	*AHCC, WCC*	*Inmates in maximum security area can watch nature videos on a computer monitor*
Diversity garden	*AHCC*	*Cultural groups grow food and flowers for their special events*
Heritage Garden	*CRCC*	*Inmates designs that honor the cultural and natural heritage of our local area, using native plants to minimize water use*
House plants	*LCC*	*Only WA prison with house plants in inmate rooms*
	MCC	*Houseplants on hospital floor*
	WCC	*In all shared and staff areas*
	WSP	*Throughout SPL and staff areas*
Flower gardens, boxes, baskets	*AHCC, CCC, LCC, SCCC, WCC WCCW*	*Ornamental and pollinator-friendly plantings throughout the main and minimum areas*
	CBCC	*Ornamental gardens in courtyard and access breezeway*
	MCC	*Flower gardens are grown to attract bees to pollinate the vegetables.*
	OCC	*Pollinator-friendly plantings in the Horticulture area; each living unit has several garden beds planted and maintained by residents; hanging baskets and flowering beds throughout staff and inmate areas*
	WSP	*62 rental garden boxes available in south and east complexes*
Water features	*OCC*	*Two living units have fish ponds; the other has a fountain and basin*
Chickens	*OCC, WCCW*	*All eggs donated to partners*



Due to the enthusiasm of staff and inmates, beekeeping programs were a major focus of the the Washington State DOC in 2019. Photo by Ricky Osborne, Sustainability in Prisons Project (SPP) Fiscal Year 2016 Annual Report

SOURCES: Bureau of Justice Statistics Press Release May 23, 2018 (https://www.bjs.gov/content/pub/press/18upr9yfup0514pr.pdf); SustainabilityinPrisons.org; Washington State Department of Corrections FY2019 Cost Per Offender All; Sustainability in Prisons Project Annual Report for Fiscal Years 2016 and 2019; What do prisoners Cost? by Scott North for Hearldnews.com (4/20/2011); Insight Garden Program Research Studies on Recidivism http://insightgardenprogram.org/research-studies/; The Horticultural Society of New York https://www.thehort.org/programs/greenhouse/; Table adapted from SPP (http://sustainabilityinprisons.org/spp-programs-in-wa/biophilia)

FUTURE DIRECTIONS
FOR RESEARCH & REPORTING

Biophilic experiences of the community have value at a community scale, with benefits that include public health, economic growth, and social cohesion, though the science has been relatively limited to vegetation and green space:

Research to date focuses on:

- Visual connections with nature
- Access to green space
- Tree canopy coverage

Related to:

- Real estate value
- Tourism
- Crime rate

Potential benefits of representational nature and spatial qualities of the built community environment still remain unresearched. A broader understanding of the relationship between biophilia and community outcomes could be expanded in several research areas:

- Impacts of duration of time spent in urban nature
- Perceptions of safety in public spaces relative to vegetation and landscape design
- Impacts of representational nature and spatial qualities, as well as vegetation, within and around civic structures such as libraries, community centers, police stations
- Equity and equitable access without while managing displacement risk
- Correlations between specific types of crime complaints and types of biophilic conditions in a given space/place to understand benefit-cost opportunities for urban green infrastructure/acupuncture
- Long-term studies of public health and access to green space, in particular where new parks and community gardens are added to neighborhoods
- Impact of agricultural zones, preservation and conservation easements in the urban sphere
- Multivariable accounting for green infrastructure installations
- Prosocial behavioral change

GOING FORWARD
WITH BIOPHILIC DESIGN

Much has changed in the ten years since the first edition of The Economics of Biophilia was published. The word "biophilia" now appears frequently in design magazines and the mainstream press. A number of companies, including Google and Salesforce, have adopted biophilic design standards. Biophilic design has been listed as one of the top ten design trends in hospitality for several years, and it has become integral to brands such as Westin and 1 Hotels. For many, biophilia in the built environment is limited to potted plants. Among the design community, the understanding of the human response to nature beyond vegetation has become more nuanced, as have the potential design opportunities and their relatable value to occupants and owners alike.

In academia, new subfields are taking form, for instance, alliesthesia, fractals, psychoacoustics, visual preference through eye tracking, and even neuroaesthetics. The number of scientific papers on biophilia is increasing, with research looking into where our attention is directed and what portions of the brain are responding to various experiences of nature. We now know that the experiences of prospect, refuge, mystery and awe each activate different locations within the brain. Several emerging technologies are becoming more affordable and available to researchers. Advanced mobile electroencephalography (EEG) units have led to early evidence supporting Affordance Theory—the idea that the configuration of spaces signals possible behavioral responses. Virtual reality goggles with eye tracking allow designers to prototype biophilic design interventions in virtual reality and then gauge how strongly they attract our attention. Multi-sensory design is looking to nature for inspiration, and work in the field of neuro-aesthetics is exploring subconscious emotional responses to biophilic experiences. While most of this research is exploring universal human responses, in the future we anticipate seeing more research on how biophilia can support non-neurotypical populations such as dementia patients, people living with PTSD, and children on the autism spectrum.

From a policy research and investment perspective, the opportunities presented by the implementation of biophilic design measures could also be framed in terms of forecasting and future-discounting: How do criteria for an investment factor in the long-term economic benefits of access to nature? What policies are in place to ensure that short-term investments minimize the risk of potential long-term impacts to a company or community and its most valuable asset—its people? Finally, which policies, incentives, and lobbying practices are most likely to hinder or upend initiatives aimed at optimizing an existing or potential biophilic experience or investment?

Biophilic design is a component of many building certification systems, including LEED, WELL, BREEAM and the Living Building Challenge. Recognition of the potential impact of biophilic urban design is increasingly focused on historically underserved communities. Our hope is that in the future biophilic design will be a universal component of the built environment, supporting the health and well-being of all people, in every community, worldwide. We also hope that this second edition of *The Economics of Biophilia* is one more step in making that vision a reality. ❖

APPENDICES

A. RESEARCH OVERVIEWS
B. CALCULATIONS
C. REFERENCES



A. RESEARCH OVERVIEWS

Ch2. OFFICES

Biophilic Attributes	Authors & Date	Impact Category		
		Reduced Stress & Sickdays	Cognitive Function & Job Performance	Mood, Preference & Job Satisfaction
Views to Nature	Ulrich et al., 1991	X		
Views to Nature	Lottrup, Grahn & Stigsdotter, 2013	X		X
Views to Nature	Lottrup et al., 2015		X	X
Plants & Views to Nature	An et al., 2016	X		X
Plants & Views to Nature	Dravidge 2008	X		X
Views & Daylight	Elzeyadi, 2011	X		
Views to Nature	Heschong, 2003		X	
Indoor Plants & Daylight	Interface, 2015	X	X	X
Indoor Plants	CBRE, 2017	X	X	X
Indoor Plants	Lohr et al., 1996	X	X	
Indoor Plants	Nieuwenhuis et al., 2014		X	X
Indoor Greenery	Toyoda et al., 2020	X		
Interior Wood	Shen et al., 2020		X	
Water Sounds	Haapakangas, 2011		X	
Nature Sounds	Van Hedger et al., 2019		X	
Nature Sounds	Alvarrson et al., 2010	X		X
Nature Sounds	Annerstedt et al., 2013	X		
Indoor Elements & Views to Nature	Yin et al., 2018	X	X	
Simulated Indoor Biophilic Elements	Yin et al., 2019	X	X	

Ch3. EDUCATION

Biophilic Attributes	Authors & Date	Impact Category			
		Stress & Wellbeing	Environmental Satisfaction & Behavioral Outcomes	Cognitive Function & Test Performance	Graduation Rate
Biomorphic Forms & Patterns, Views to Nature	Determan et al., 2019	X	X	X	
Indoor Plants	Han, 2009	X	X		
Indoor Plants	van den Bogerd et al., 2020		X		
Nature Sounds	Shu & Ma, 2019			X	
Views to Nature	Li & Sullivan, 2016	X	X	X	
Views to Nature	Benfield et al., 2015		X	X	
Views to Nature	Matsuoka, 2010		X	X	X
Walk in Nature	Taylor & Kuo, 2009			X	
Greenness of Home, School and Commute	Dadvand et al., 2015			X	
School Greenness	Wu et al., 2014			X	
School Greenness	Kweon et al., 2017			x	
Outdoor Learning	Williams & Dixon, 2013			x	
Outdoor Learning	Kuo, Browning & Penner, 2018		x	x	
Outdoor Learning	Wells et al., 2015			x	

Ch4. HEALTHCARE

Biophilic Attributes	Authors & Date	Impact Category		
		Patient Length of Stay	Patient Experience (Perceptions of pain, stress, environmental satisfaction, staff satisfaction, etc.)	Staff Wellbeing & Productivity
Views to Nature	Ulrich, 1984	X	X	
Views to Nature	Pati, Harvey & Barach, 2008			X
Views to Nature & Daylight	Joarder & Price, 2013	X		
Views to Nature & Daylight	Shepley et al., 2012			X
Daylight	Choi et al., 2012	X		
Daylight	Chiu et al., 2018	X		
Daylight	Walch et al., 2005		X	
Indoor Plants	Park & Mattson, 2008		X	
Indoor Plants	Park & Mattson, 2009	X	X	
Natural Materials & Visual Connection with Nature	Swan et al., 2003		X	
Simulated Prospect & Refuge Views	Vincent et al., 2010		X	
Simulated Views	Pati et al., 2015		X	
Views to Nature	Emami et al., 2018		X	
Nature Sounds	Watts, Khan & Pheasant, 2016		X	

Ch5. RETAIL

Biophilic Attributes	Authors & Date	Impact Category	
		Customer Perception	Shopping Behavior
Indoor vegetation	Brengman, Willems & Joye, 2012	X	X
Indoor vegetation	Rosenbaum, Otalora & Ramirez, 2016	X	X
Indoor vegetation and biomorphic vase	Tifferet & Vilnai-Yavetz, 2017	X	
Indoor vegetation, animals, water, and sight protection (refuge)	Buber et al., 2007	X	
Simulated courtyard with greenery, bird flight and water feature	Rosenbaum, Ramirez & Camino, 2018	X	X
Biophilic interior	Ortégon-Cortázar & Royo-Vela, 2019		X
Storefront Aquarium	Windhager et al., 2011		X
Outdoor vegetation	Wolf, 2003	X	X
Outdoor vegetation	Wolf, 2004	X	
Outdoor vegetation	Wolf, 2005	X	X

Ch6. HOSPITALITY

Biophilic Attributes	Authors & Date	Impact Category	
		Customer Perception	Room Rate
View to lake	Lange & Schaeffer, 2001		X
View to water or garden	Browning et al., 2016		X
Plants in guest rooms	McMillin, 2019	X	X
Indoor vegetation in quest rooms	Berg, 2019	X	
Greenery, natural finishes and natural light	Purani & Kumar, 2018	X	
Biophilic lobbies	Browning et al., 2016	X	
Biophilic lobbies	Lee, 2019	X	

Ch7. COMMUNITY

Biophilic Attributes	Authors & Date	Impact Category			
		Public Health	Crime & Aggression Reduction	Community Cohesion & Pro-social Behavior	Real Estate Value & Tourism
Common Green Space	Giles-Corti et al., 2005	X			
Common Green Space	Kuo & Sullivan 2001a		X		
Common Green Space	Kuo & Sullivan 2001b		X		
Common Green Space	Kuo et al., 1998			X	
Common Green Space	Deng et al., 2010				X
Common Green Space	Harnik & Welle, 2009				X
Community Gardens	Voicu & Been, 2008				X
Urban Greenery	Tilt, Unfried & Roca, 2007	X			
Urban Greenery	Maas et al., 2006	X			
Urban Greenery	Kardan et al., 2015	X			
Urban Greenery	Brown et al., 2016	X			
Urban Greenery	Troy, Grove & O'Neil-Dunne, 2012		X		
Urban Greenery	Gilstad-Hayden et al., 2015		X		
Urban Greenery	Burley, 2018		X		
Urban Greenery	Donovan & Butry, 2010				X
Self-reported Nature Connectedness	Fido & Richardson, 2019			X	
Self-reported Nature Connectedness	Metz, 2017			X	
Visual Connection with Nature	Zelenski, Doplo & Capaldi, 2015			X	
Visual Connection with Nature	Weinstein et al., 2009			X	
Exposure to Nature	Van der Wahl, et al., 2013			X	
Proximity to Nature	Wolf, 2010				X

B. CALCULATIONS

Ch2. OFFICES

Calculations in this report are conducted in the currency at the year of research publication and have been converted to 2022 values (as of April 2022) using online tools available through the American Institute for Economic Research (www.aier.org).

1. EMPLOYEE COSTS AS A PERCENTAGE OF TOTAL OFFICE COSTS PER SQUARE FOOT

Professional and business-services employers pay on average $93,516.80 per year in total compensation per employee (Bureau of Labor Statistics, 2021). The average office space per employee in 2018 was 193.8 ft2 (Cushman & Wakefield, 2018). By dividing the average total compensation per employee by the average square footage per employee, we determine the average total compensation per square foot is $482.54. Adding base office rent per square foot ($24.27) (BOMA, 2018) and total office operating expenses per square foot ($8.07) (BOMA, 2016), we arrive at a total office operating expenditure of $514.88 per square foot per year. As a percentage of total office operating expenditures per square foot per year, total employee compensation per square foot accounts for 93.7% ($482.54 ÷ $514.88).

2. ABSENTEEISM AND PRESENTEEISM COSTS

The average professional and business-services employee is found to lose 3% of their work year due to absenteeism and presenteeism (Bureau of Labor Statistics, 2020; Mitchell & Bates, 2011; Chimed-ochir et al., 2019). Presenteeism is considered to be the time when the employer's contribution to the employee is unproductive (no contribution in return). Given their average annual total compensation of $93,516.80, $2,805.50 of each employee's yearly total compensation is considered unproductive (3% of $93,516.80). As a more realistic approximation of the lost revenue from 3% of each employee's work time being lost, we use the average revenue a professional-services employee is estimated to bring in per year ($331,562) (CSI Market, 2020). Lost revenue due to lost work time would then equal $9,946.86 (3% of $331,562). Across an office of 200 employees, that lost revenue per employee would add up to $1,989,372 ($9,946.86 × 200).

3. INCREASED REVENUE FROM MORE TIME SPENT WORKING

Elzeyadi (2011) found that employees with quality views worked an average of 11 hours more than those without a view. The average hourly revenue per professional services employee is estimated to be $159.40 ($331,562 (CSI Market, 2020) ÷ 2080 work hours per year). The addition of 11 hours would increase annual revenue by $1,753.40 (11 hours × $159.40 in revenue per hour). Across an office of 200 employees, the increased revenue per employee would add up to $350,680.

4. IMPROVED COGNITIVE PERFORMANCE FROM NATURE SOUNDS

Van Hedger et al. (2019) used two cognitive tests to estimate improved cognitive performance. Both are assessments of directed attention. In this study, the scores for the backwards digital span (BDS) test before and after exposure to nature sounds were 9.74 and 10.61 respectively, and the scores for the dual n-back (DNB) test before and after exposure to nature sounds were 1.49 and 1.77 respectively. As such, the percent change (improvement) between pre- and post-nature-sound exposure was 8.93% for the BDS test and 18.79% for the DNB test. The average percentage improvement between both tests was 13.9%.

5. SAVINGS FROM REDUCED VOLUNTARY JOB SEPARATION

An average 11% increase in productivity was found due to biophilic design interventions: 6.5% (Heschong, 2003), 12% (Heschong, 2003), 6% (Interface, 2015), 10% (CBRE, 2017), 12% (Lohr et al., 1996), 15% (Nieuwenhuis et al., 2014), 9% (Shen et al., 2020), 13.9% (Van Hedger et al., 2019) and 14% (Yin et al., 2018). Assuming increasing productivity by 11% would cause an 11% increase in that employee's annual revenue contribution (baseline $331,562 per employee per year), each employee would bring in an additional $36,471 per year. Across an office of 200 employees, the increased annual revenue per employee would add up to $7,294,364

6. IMPROVED JOB SATISFACTION & LIFE QUALITY FROM PLANTS

Dravidge et al. (2008) used a survey to assess job satisfaction and life quality among employees with and without plants and windows (scores in Table 2 and Table 3 of the study). Among conditions that did not include plants, job satisfaction and life quality scores averaged 106.02 and 3.68, respectively. Among conditions that included plants, job satisfaction and life quality scores averaged 113.84 and 3.98, respectively. As such, those with plants in the office had 7.38% higher job satisfaction scores, and 8.15% higher life quality scores.

7. SAVINGS FROM REDUCED VOLUNTARY JOB SEPARATION

A potential 10 percentage point decrease in the job separation rate across an office of 200 employees would mean 20 fewer employees quit per year. The average annual salary of a professional and business services employee is $67,163.20 (BLS, 2021). Given that the cost of separation was found to equal 30% of the employee's salary (Work Institute, 2020), each employee retained would save the company $20,148.96. For the 20 employees who were retained, yearly savings to the company would amount to an estimated $402,979.20 ($20,148,96 per employee × 20 employees).

Ch3. EDUCATION

No supplemental calculations.

Ch4. HEALTHCARE

Calculations are conducted in the currency at the year of research publication and have been converted to 2022 values (as of April 2022) using online tools available through the American Institute for Economic Research (www.aier.org).

1. SAVINGS ASSOCIATED WITH REDUCED ALoS

To estimate the potential hospital cost savings associated with a shorter average length of stay, we first calculated an approximate average number of inpatient visits a hospital might have in a year (35.7 million inpatient visits nationally (Freeman, Weiss & Heslin, 2018) ÷ 6,146 US hospitals (AHA, 2021) yields ~5,809 in-patient visits per hospital). We then determined the average reduction in average length of stay (ALoS) that occurred via biophilic design interventions. Across the studies we assessed (Ulrich, 1984; Joarder & Price, 2013; Choi et al., 2012; Chiu et al., 2018; Park & Mattson, 2009), there was an average 18.1% reduction in ALoS. Using the average length of stay across the US (5.5

days (OECD, 2021)) as a baseline, the 18.1% reduction corresponds to a 0.99-day reduction (5.5 days × 18.1%). We then calculated the corresponding reduction in hospital expenses per patient from a 0.99-day shorter stay (average hospital expenses per inpatient day of $2,143 (Ellison, 2019) multiplied by 0.99-day reduction) to get $2,128.47. Finally, we calculated the annual expense saving across the hospital by multiplying the reduced expense per patient ($2,128.47) with the average number of inpatient visits per hospital per year (5,809). Thus we show a $12,363,559 decrease in annual hospital expenses by way of ALoS-reducing biophilic design interventions.

2. INCREASED WILLINGNESS TO RECOMMEND

One study found that a patient's willingness to recommend the hospital increased by 3.4% for those who experienced a more pleasing hospital environment (Swan, Richardson & Hutton, 2003). According to Richter & Muhlestein (2017), the correlation between patient experience and profitability is such that for every 1.0% increase in the percentage of people who would "definitely recommend" the hospital, the hospital is expected to net an increase of $1,072,000 in patient revenue and a 0.04% in operating margins. To find the increase in patient revenue associated with a 3.4% increase in willingness to recommend, we multiplied $1,072,000 by 3.4 to yield $3,644,800. To find the increase in operating margins, associated with a 3.4% increase in willingness to recommend, we multiplied 0.0004 by 3.4, which equals 0.14%.

3. RECUPERATED OPERATING EXPENSES FROM REDUCED STAFF TURNOVER

Hall (2005) found that average staff turnover costs accounted for 5% of a hospital's operating budget. A biophilic hospital environment was shown to decrease staff turnover by 25% in one study (Shepley et al., 2012). To find the associated impact that reducing staff turnover by 25% has on a hospital's operating budget, we multiplied 0.05 by 0.25, which equals 1.25% of a hospital's operating budget that no longer needs to be spent on staff turnover costs.

Ch5. RETAIL

1. MORE SPENDING PER TRANSACTION FROM IMPROVED CUSTOMER PERCEPTIONS

The average small business is said to make 13 transactions per day averaging $74.65 per transaction (Womply, n.d.). That business would then make an average of $970.45 per day ($74.65 per transaction × 13 daily transactions), or $303,750.85 per year, assuming they are open 313 days per year (~6 days per week). Maxham, Netemeyer, and Lichtenstein (2008) found that a one-point increase in customer evaluation scores (on a seven-point scale) corresponded with a 15% increase in customer spending per store visit. Given the various aforementioned studies citing improved store and staff perceptions from biophilic design interventions, we concluded that a one-point increase in customer evaluations (and subsequent 15% increase in transactional spending) from biophilic design was a fair estimate. To calculate the subsequent increase in revenue, we multiply the $970.45 revenue per year by 15%, which shows an increase of $145.57 per day. Multiplying the daily increase in revenue by the 313 days in operation per year, we conclude a $45,562.63 increase in annual revenue by way of improved customer perceptions. The decision point would then be to weigh the cost of the biophilic intervention in comparison to the potential increased revenue.

2. WILLINGNESS TO PAY MORE FROM BIOPHILIC STOREFRONT

Wolf (2005) found that people were willing to pay between 15% and 25% more in vegetated retail settings. Assuming a more modest 10% increase in prices would be acceptable for shoppers in the biophilic retail setting (detailed in appendix B1) as compared to a conventional setting, the business would then see $384,244.83 in annual revenue (1.10

× $349,313.48). To get the difference in revenue pre and post 10% price increase, we subtract $349,313.48 from $384,244.83 to get $34,931.35 in additional revenue per year. This calculation then must be greater than the cost of the biophilic elements to offset the projected increase in revenue.

3. INCREASED SALES VOLUME FROM HIGHER FOOT TRAFFIC

We assume that a biophilic retail setting would see one additional unit of foot traffic per hour, which corresponds to an increase of $9.97 in average hourly sales volume (Perdikaki, Kesavan & Swaminathan, 2012). Assuming the store is open for 11 hours per day, this would correspond to a $109.67 increase in revenue per day ($9.97 per hour × 11 hours per day). Assuming the business is in operation for 313 days per year (~6 days per week), this would translate to a $34,426.71 increase in annual revenue ($109.67 in increased revenue per day × 313 days of operation per year).

Ch6. HOSPITALITY

No supplemental calculations.

Ch7. COMMUNITY

Calculations are conducted in the currency at the year of research publication and have been converted to 2022 values (as of April 2022) using online tools available through the American Institute for Economic Research (www.aier.org).

1. DECREASE IN HEALTHCARE SPENDING

To calculate the potential for reduced healthcare spending across a community, we first calculated the average healthcare spending for a healthy individual versus an individual with chronic health problems. According to Claxton, Sawyer, and Cox (2019), the average combined expenses (premium contribution and out-of-pocket expenses) for an individual in good health was $5,110 per year, whereas the same costs for someone in poor health was $7,815 per year. This means a person in poor health pays an average $2,705 more per year than someone in good health. Brown et al. (2016) found that among residents of Miami-Dade County in Florida, those in areas with one standard deviation above the average vegetative index had 49 fewer cases of chronic disease than those in areas with one standard deviation below average vegetative index. In a community of 100,000 residents, that's equivalent to 4,900 fewer cases of chronic disease. If 4,900 fewer people had chronic diseases, that would be equivalent to $13,254,500 less in healthcare spending per year across the community ($2,705 less per person × 4,900 fewer people in poor health).

2. NEW HAVEN CRIME REDUCTION

A 10% increase in street trees has been associated with a 14% reduction in crime in New Haven, CT (Gilstad-Hayden et al., 2015). The city's crime rate at the time of this study was 68.1 crimes per 1,000 people per year. Given New Haven's population of approximately 130,000, there are an estimated 8,853 crimes committed each year. According to Gilstad-Hayden et al. (2015), if the entire city experienced a 10% increase in street trees, the crime rate would reduce by 1,239 crimes each year (8,853 crimes × 14% reduction).

C. REFERENCES

Ch1. INTRODUCTION

Africa, J., Heerwagen, J., Loftness, V., & Ryan Balagtas, C. (2019). Biophilic Design and Climate Change: Performance Parameters for Health. *Front. Built Environ.,* 19 March 2019. Sec. Urban Science. https://doi.org/10.3389/fbuil.2019.00028

Biederman I., & Vessel E.A. (2006). Perceptual pleasure and the brain. *American Scientist, 94*, 249–255.

Bratman, G., Hamilton, J.P., Hahn, K., Daily, G., & Gross, J. (2015). Nature experience reduces rumination and subgenual prefrontal cortex activation, Proceedings of the National Academy of Sciences, doi: 10.1073/pnas.1510459112.

Brown, D.K., Barton, J.L., & Gladwell, V.F. (2013). Viewing Nature Scenes Positively Affects Recovery of Autonomic Function Following Acute-Mental Stress. *Environmental Science & Technology, 47,* 5562–5569.

Browning, W., Ryan, C., & Clancy, J. (2014). 14 Patterns of Biophilic Design, New York: Terrapin Bright Green, LLC.

Browning, W., & Ryan, C. (2020). *Nature Inside, A Biophilic Design Guide*. London: Royal Institute of British Architects.

Cambridge Institute for Sustainability Leadership (2023). Nature positive Hub, University of Cambridge. Last accessed 23 May 2023, from https://www.cisl.cam.ac.uk/resources/nature-positive

Chatterjee, A. (2023) Neuroaesthetics, Architecture, and Biophilia, a presentation at the Biophilic Leadership Summit on 24 April 2023, Serenbe, GA.

Cowen, A.S. & Keltner, D. (2017). Self-report captures 27 distinct categories of emotion bridged by continuous gradients. Proceedings of National Academy of Sciences, 114(38). Sec. Psychological and cognitive sciences. https://doi.org/10.1073/pnas.1702247114

ILFI (2022). Biophilic Design Toolkit. International Living Future Institute. https://www2.living-future.org/biophilicdesigntoolkit

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *J. Environ. Psychol., 15,* 169–182.

Kellert, S., Heerwagen, J.H., & Mador, M. (2008). *Biophilic design: The theory, science, and practice of bringing buildings to life*. Hoboken, New Jersey: John Wiley & Sons, Inc.

Keller, S.R. & Willson, E.O. (1993). *The Biophilia Hypothesis*. Island Press: Washington, DC. ISBN: 1-55963-148-1

Lee, K., Williams, K., Sargent, L., Williams, N., & Johnson, K. (2015). 40-second green roof views sustain attention: The role of micro-breaks in attention restoration. *J. Environ. Psychol., 42,* 182–189.

Maas, J. (2011). Take a hike! How attention restoration theory shows that nature sharpens the mind. *Ode for Intelligent Optimists, 8*(4).

Park, B.J., Tsunetsugu, Y., Kasetani, T., Kagawa, T., & Miyazaki, Y. (2010). The physiological effects of Shinrin-yoku (taking in the forest atmosphere or forest bathing): evidence from field experiments in 24 forests across Japan. *Environmental Health and Preventative Medicine, 15,* 18–26.

Piff, P.K., Dietze, P., Feinberg, M., Stancato, D.M., & Keltner, D. (2015) 'Awe, the small self, and prosocial behavior', *Journal of Personality and Social Psychology, 108*(6), 883–899. http://dx.doi.org/10.1037/pspi0000018

Shen, J., Zhang, X. & Zhiwei, L. (2020). Impact of Wooden Versus Nonwooden Interior Designs on Office Workers' Cognitive Performance. *Perceptual & Motor Skills, 127*(1). https://doi.org/10.1177/0031512519876395

Ulrich, R.S. (1983). Aesthetic and affective response to natural environment. In I. Altman & J. Wohlwill (Eds), *Human Behaviour and Environment, 6*. DOI: 10.1007/978-1-4613-3539-9_4

U.S. Bureau of Economic Analysis. (2021). Outdoor Recreation Satellite Account, U.S. and States, 2020, retrieved on 18 Nov 2022, https://www.bea.gov/news/2021/outdoor-recreation-satellite-account-us-and-states-2020

Wilson, E.O. (1984). *Biophilia: The Human Bond with Other Species*. Cambridge: Harvard University Press.

World Economic Forum (WEF). (2020, January). Nature Risk Rising: Why the Crisis Engulfing Nature Matters for Business and the Economy. New Nature Economy Report series. Last accessed on 17 January 2023 at https://www.weforum.org/reports/new-nature-economy-report-series/nature-risk-rising

Yin, J., Zhu, S.H., Piers MacNaughton, P., Joseph G. Allen, J.G., & Spengler, J.D. (2018). *Building and Environment, 132*: 255–262. https://doi.org/10.1016/j.buildenv.2018.01.006



FIGURE E. Mystery, complexity and order at the market in Sarajevo. Photo by Chris Spencer-Payne on Pixabay

CH2. OFFICES

Alvarsson, J.J., Wiens, S., & Nilsson, M.E. (2010). Stress Recovery during Exposure to Nature Sound and Environmental Noise. *Int. J. Environ. Res. Public Health, 7*(3), 1036–1046.

American Society of Interior Designers. (2018). Impact of Design Series, Volume 1: ASID HQ Office." American Society of Interior Designers Research. Washington, DC.

Amanor-Boadu, Vincent. (November 2022). Empirical evidence for the "Great Resignation". Monthly Labor Review, U.S. Bureau of Labor Statistics. Last accessed 24 February 2023, from https://doi.org/10.21916/mlr.2022.29

An, M., Colarelli, S.M., O'Brien, K., & Boyajian, M.E. (2016). Why We Need More Nature at Work: Effects of Natural Elements and Sunlight on Employee Mental Health and Work Attitudes. *PLoS ONE, 11*(5), doi:10.1371/journal.pone.0155614

Annerstedt, M., Jönsson, P., Wallergård, M., Johansson, G., Karlson, B., Grahn, P., Hansen, A.M., & Währborg, P. (2013). Inducing physiological stress recovery with sounds of nature in a virtual reality forest–results from a pilot study. *Physiology & Behavior, 118*, 240–50. doi: 10.1016/j.physbeh.2013.05.023.

Brick, S. (2022). Improving health in the military and beyond using salutogenic design. *Facilities, 40*(15/16), 54–71. doi: 10.1108/F-06-2021-0058

Benfield, J.A., Taff, B.D., Newman, P., & Smyth, J. (2014). Natural Sound Facilitates Mood Recovery. *Ecopsychology, 6*(3), 183–188. doi: 10.1089/eco.2014.0028

BOMA International. (2016). BOMA 2016 Experience Exchange Reports Released. *Facility Executive*. https://facilityexecutive.com/2016/07/boma-2016-experience-exchange-reports/

BOMA International. (2018). BOMA International's Office and Industrial Benchmarking Reports Released. BOMA International & Kingsley Associates. https://www.boma.org/BOMA/Research-Resources/3-BOMA-Spaces/Newsroom/PR91818.aspx

Browning, W.D., & Walker, D.B. (2018). An Ear for Nature: Psychoacoustic strategies for workplace distraction and the bottom line. New York: Terrapin Bright Green, LLC.

Bureau of Labor Statistics (2020). Labor Force Statistics from the Current Population Survey: Household data annual averages: Table 47. Absences from work of employed full-time wage and salary workers by occupation and industry. https://www.bls.gov/cps/cpsaat47.htm

Bureau of Labor Statistics. (2021). Employer Costs for Employee Compensation: Table 4. Employer Costs for Employee Compensation for private industry workers by occupational and industry group. United States Department of Labor. Washington, DC. https://www.bls.gov/news.release/pdf/ecec.pdf

Bureau of Labor Statistics. (2021). Job Openings and Labor Turnover Survey News Release. Table 18: Annual quits rates by industry and region, not seasonally adjusted. https://www.bls.gov/news.release/archives/jolts_03112021.htm

Buskermolen, W. (2019). Tenants' willingness to pay for healthy office workplace aspects: The identification of healthy office workplace aspects that are beneficial to invest in by landlords through investigating preferences of tenants regarding trade-offs between particular aspects. Eindhoven University of Technology: Built Environment.

Candido, C., Chakraborty, P. & Tjondronegoro, D. (2019). The rise of office design in high-performance, open-plan environments. *Buildings, 9*(4). doi:10.3390/buildings9040100

CBRE Netherlands. (2017). The Snowball Effect of Healthy Offices. CBRE Healthy Offices Research Team. https://cbrenl.uberflip.com/i/823602-the-snowball-effect-of-healthy-offices/9?m4=

Chimed-Ochir, O., Nagata, T., Nagata, M., Kajiki, S., Mori, K., & Fujino, Y. (2019). Potential Work Time Lost Due to Sickness Absence and Presence Among Japanese Workers. *J. Occup. Environ. Med., 61*(8), 682–688. https://doi.org/10.1097/JOM.0000000000001646

CSI Market. (2020). Professional Services Industry: Efficiency information & trends. https://csimarket.com/Industry/industry_Efficiency.php?ind=908&hist=4

Cushman & Wakefield. (2018). Space Matters: Key office trends and metrics for US occupiers. Cushman & Wakefield - Research & Insights. http://www.cushmanwakefield.us/en/research-and-insight/2018/space-matters

Dravidge, A., Waliczek, T.M., Lineberger, R.D. & Zajicek, J.M. (2008). The Effect of Live Plants and Window Views of Green Spaces on Employee Perceptions of Job Satisfaction. *J. Am. Soc. Hortic. Sci., 43*(1), 183–187. https://doi.org/10.21273/HORTSCI.43.1.183

Determan, J., Akers, M.A., Albright, T. Browning, B. Martin-Dunlop, C., Archibald, P. & Caruolo, V. (2019). Impact of Biophilic Learning Spaces on Student Success. Retrieved December 1, 2020, from https://cgdarch.com/wp-content/uploads/2019/12/The-Impact-of-Biophilic-Learning-Spaces-on-Student-Success.pdf

Elzeyadi, I. (2011). "Daylighting-Bias and Biophilia: Quantifying the Impacts of Daylight on Occupants Health." In: Thought and Leadership in Green Buildings Research. Greenbuild 2011 Proceedings. Washington, DC: USGBC Press.

Evans, G.W. & Johnson, D. (2000). Stress and open-office noise. *Journal of Applied Psychology, 85*(5), 779–783.

Gallup. (2020). Gallop's perspective on employee burnout: Causes and cures. https://www.gallup.com/workplace/282659/employee-burnout-perspective-paper.aspx

Haapakangas, A., Helenius, R., Keskinen, E., & Hongisto, V. (2008). Perceived Acoustic Environment, Work Performance and Well-being – Survey Results from Finnish Offices. 9th International Congress on Noise as a Public Health Problem (ICBEN).

Haapakangas, A., Kankkunen, E., Hongisto, V., Virjonen, P., & Keskinen, E. (2011). Effects of Five Speech Masking Sounds on Performance and Acoustic Satisfaction. Implications for Open-Plan Offices. *Acta Acustica united with Acustica, 97*, 641–655.

Harter, J.K., Schmidt, F.L. & Keyes, C.L.M. (2003). Well-being in the work-place and its relationship to business outcomes: A review of the Gallup studies. In C.L.M. Keyes and J. Haidt (eds), Flourishing, Positive Psychology and the Life Well-lived. Washington D.C., USA: American Psychological Society.

Heschong, L. Heschong Mahone Group. (2003). Windows and Offices: A Study of Office Worker Performance and the Indoor Environment. California Energy Commission: Pacific Gas and Electric Company. Fair Oaks, California.

Hongisto, V. (2005). A model predicting the effect of speech of varying intelligibility on work performance. *Indoor Air, 15*, 458–468.

OFFICES (CONT.)

Hongisto, V., Haapakangas, A. & Haka, M. (2008). Task performance and speech intelligibility – a model to promote noise control actions in open offices. 9th International Congress on Noise as a Public Health Problem (ICBEN).

Interface. (2015). Human Spaces: The Global Impact of Biophilic Design in the Workplace. https://www.interface.com/APAC/en-AU/about/press-room/Human-Spaces-Report-Press-Release-en_AU

Jahncke, H., Hygge, S., Lahin, N., Green, A.M., & Dimberg, K. (2011). Open-plan office noise: Cognitive performance and restoration. *J. Environ. Psychol., 31,* 501–509.

Judge, T.A., Thoresen, C.J., Bono, J.E., Patton, G.K. (2001). The Job Satisfaction-Job Performance Relationship: A Qualitative and Quantitative Review. *Psychological Bulletin, 127*(3), 376–407.

Katebi, A., HajiZadeh, M.H., Bordbar, A. et al. The Relationship Between "Job Satisfaction" and "Job Performance": A Meta-analysis. Glob *J Flex Syst Manag 23,* 21–42 (2022). https://doi.org/10.1007/s40171-021-00280-y

Loftness, V., Aziz, A. & Son, Y. (2019) POE+M Study of Interface HQ Work Environments Draft (v10), Center for Building Performance and Diagnostics, Carnegie Mellon University, December 2019.

Lohr, V.I., Pearson-Mims, C.H. & Goodwin, G.K. (1996). Interior plants may improve worker productivity and reduce stress in a windowless environment. *J. Environ. Hortic., 14*(2), 97–100. https://doi.org/10.24266/0738-2898-14.2.97

Lottrup, L., Grahn, P. & Stigsdotter, U.K. (2013). Workplace greenery and perceived level of stress: Benefits of access to a green outdoor environment at the workplace. *Landscape & Urban Planning, 110,* 5–10.

Lottrup, L., Jensen, A.G. & Stigsdotter, U.K. (2015). The Workplace Window View: A Determinant of Office Workers' Work Ability and Job Satisfaction. Landscape Research, 40(1). doi: 10.1080/01426397.2013.829806

Margolies, J. (2019). The Next Frontier in Office Space? The Outdoors. The New York Times. https://www.nytimes.com/2019/01/15/business/office-buildings-nature-biophilia.html

Mitchell, R.J. & Bates, P. (2011). Measuring Health-Related Productivity Loss. Population Health Management, 14(2). doi: 10.1089/pop.2010.0014

Nieuwenhuis, M., Knight, C., Postmes, T. & Haslam, S.A. (2014). The Relative Benefits of Green Versus Lean Office Space: Three Field Experiments. Journal of Experimental Psychology: Applied. http://dx.doi.org/10.1037/xap0000024

Park, S.H., Lee, P., Lee, B.K., Roskams, M. & Haynes, B. (2020). Associations between job satisfaction, job characteristics, and acoustic environment in open-plan offices. Applied Acoustics, 168. https://doi.org/10.1016/j.apacoust.2020.107425

Pheasant, R.J., Fisher, M.N., Watts, G.R., Whitaker, D.J., & Horoshenkov, K.V. (2010). The importance of auditory-visual interaction in the construction of 'tranquil space.' J. Environ. Psychol, 30, 501–509.

Schneider, A., Hilbert, S., Hamann, J., Skadsem, S., Glaser, J., Löwe, B. & Bühner M. (2017). The Implications of Psychological Symptoms for Length of Sick Leave. Deutsches Arzteblatt International, 114(17), 291–297. doi: 10.3238/arztebl.2017.0291

Sears, L.E., Shi, Y., Coberley, C.R. & Pope, J.E. (2013). Overall Well-Being as a Predictor of Health Care, Productivity, and Retention Outcomes in a Large Employer. Population Health Management, 16(6). doi: 10.1089/pop.2012.0114

Shen, J., Zhang, X., & Zhiwei, L. (2020). Impact of Wooden Versus Nonwooden Interior Designs on Office Workers' Cognitive Performance. Perceptual & Motor Skills, 127(1). https://doi.org/10.1177/0031512519876395

Smith, R.A. (22 February 2023). How Hybrid Work is Changing Offices of the Future. The Wall Street Journal, sec. The Future of Everything. Last accessed 24 February 2023, from https://www.wsj.com/articles/how-hybrid-work-is-changing-offices-of-the-future-275d7368

The American Institute for Stress. (n.d.). Workplace Stress. The American Institute for Stress. https://www.stress.org/workplace-stress/

Toyoda, M., Yokota, Y., Barnes, M., & Kaneko, M. (2020). Potential of a Small Indoor Plant on the Desk for Reducing Office Workers' Stress. HortTechnology, 30(1), 1–9.

Turan, I., Chegut, A., Fink, D., & Reinhart, C. (2020). The value of daylight in office spaces. Building & Environment, 168(15). https://doi.org/10.1016/j.buildenv.2019.106503

Ulrich, R.S., Simons, R.F., Losito, B.D., Fiorito, E., Miles, M.A. & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. J. Environ. Psychol, 11(3), 201–230. https://doi.org/10.1016/S0272-4944(05)80184-7

Van Hedger, S.C., Nusbaum, H.C., Clohisy, L., Jaeggi, S.M., Buschkuehl, M. & Berman, M.G. (2019). Of cricket chirps and car horns: the effect of nature sounds on cognitive performance. Psychonomic Bulletin & Review, 26, 522–530.

Work Institute. (2020). 2020 Retention Report: Insights on 2019 turnover trends, reasons, costs & recommendations. Retrieved from https://workinstitute.com/retention-report/

Work Institute. (2021). Mid-Year 2021 Retention Report: Reasons for Leaving Shift as Open Jobs Skyrocket. Retrieved from https://workinstitute.com/retention-report/

The World Bank. (n.d.). World development indicators: Structure of output. World Bank National Accounts. The World Bank Group. Retrieved April 22, 2021, from http://wdi.worldbank.org/table/4.2#

WGBC. (2018). Doing Right by Planet and People: The Business Case for Health and Wellbeing in Green Building. World Green Building Council.

World Health Organization. (2019, May 28). Burn-out an "occupational phenomenon": International classification of diseases. World Health Organization. Retrieved November 10, 2020, from https://www.who.int/news/item/28-05-2019-burn-out-an-occupational-phenomenon-international-classification-of-diseases

Yin, J., Zhu, S., MacNaughton, P., Allen, J.G., & Spengler, J.D. (2018). Physiological and cognitive performance of exposure to biophilic indoor environment. *Building and Environment, 132,* 255–262. https://doi.org/10.1016/j.buildenv.2018.01.006

Yin, J., Arfaei, N., MacNaughton, P., Catalano, P.J., Allen, J.G., & Spengler, J.D. (2019). Effects of biophilic interventions in office on stress reaction and cognitive function: A randomized crossover study in virtual reality. *Indoor Air, 29,* 1028–1039.

Ch3. EDUCATION

Alliance for Excellent Education. (2018). "High School Graduation Rates and Their Effect on the American Economy. "https://all4ed.org/event/the-graduation-effect-high-school-graduation-rates-and-their-effect-on-the-american-economy/

Baker, B.D. (2017). How Money Matters for Schools. Learning Policy Institute: School Finance Series. https://learningpolicyinstitute.org/product/how-money-matters-report

Barrette, P., Davies, F., Zhang, Y. & Barrett, L. (2015). The impact of classroom design on pupils' learning: Final results of a holistic, multi-level analysis. *Building & Environment, 89,* 118–133. http://dx.doi.org/10.1016/j.buildenv.2015.02.013

Benfield, J.A., Rainbolt, G.N., Bell, P.A. & Donovan, G.H. (2015). Classrooms With Nature Views: Evidence of Differing Student Perceptions and Behavior. *Environment & Behavior, 47*(2), 140–157. DOI: 10.1177/0013916513499583

Bentsen, P. & Jensen, F.S. (2012). The nature of udeskole: Outdoor learning theory and practice in Danish schools. *Journal of Adventure Education & Outdoor Learning, 12*(3), 199–219. doi:10.1080/14729679.2012.699806

Bowman, C., Bowman, R. & Bowman, D. (2019, August). The Biophilic Classroom Study. Putney High School Girls' Day School Trust. https://www.gdst.net/publications/the-biophilic-classroom

Bureau of Labor Statistics. (2017). Current Population Survey. Median weekly earnings (in dollars) and unemployment rate (in percent) by educational attainment, 2017. https://www.bls.gov/careeroutlook/2018/data-on-display/education-pays.htm

Dadvand, P., Nieuwenhuijsen, M.J., Esnaola, M., Forns, J., Basagaña, X., Alvarez-Pedrerol, M., Rivas, I., López-Vicentea, M., De Castro Pascual, M., Su, J., Jerrett, M., Querol, X. & Sunyer, J. (2015). Green spaces and cognitive development in primary schoolchildren. *Proceedings of the National Academy of Sciences of the United States of America, 112*(26), 7937–7942.

Determan, J., Akers, M.A., Albright, T. Browning, B. Martin-Dunlop, C., Archibald, P. & Caruolo, V. (2019). Impact of Biophilic Learning Spaces on Student Success. Retrieved December 1, 2020, from https://cgdarch.com/wp-content/uploads/2019/12/The-Impact-of-Biophilic-Learning-Spaces-on-Student-Success.pdf

Elements Nature Preschool. 2018. Curriculum and Intention. Retrieved March 11, 2021, from http://elementspreschool.com/curriculum/

Han, K. (2009). Influence of limitedly visible leafy indoor plants on the psychology, behavior, and health of students at a junior high school in Taiwan. *Environment and Behavior, 41*(5), 658–692. doi: 10.1177/0013916508314476

Hanushek, E.A., Ruhose, J. & Woessmann, L. (2017). Economic Gains from Educational Reform by US States. *Journal of Human Capital, 11*(4). https://doi.org/10.1086/694454

Jackson, C.K. (2018). Does School Spending Matter? The New Literature on an Old Question. Presented at the Fall 2018 Bronfenbrenner Center for Translational Research Conference, WORKING PAPER 25368. DOI 10.3386/w25368

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *J. Environ. Psychol., 15,* 169-182.

Kim, S. C., Pope, J., & Romito, K. (Eds.). (2020, May 27). Teenage Sleep Patterns. University of Michigan Health. Retrieved April 24, 2021, from https://www.uofmhealth.org/health-library/te7279

Kuo, M., Browning, M.H.E.M. & Penner, M.L. (2018). Do lessons in nature boost subsequent classroom engagement? Refueling students in flight. *Frontiers in Psychology, 8,* 2253. DOI: 10.3389/fpsyg.2017.02253

Kweon, B., Ellis, C.D., Lee, J. & Jacobs, K. (2017). The link between school environments and student academic performance. *Urban Forestry & Urban Design, 23,* 35–43. http://dx.doi.org/10.1016/j.ufug.2017.02.002

Larkin, C., (2022). Review commentary on draft of the Economics of Biophilia 2nd edition, 17 March 2022.

Lee, K.E., Williams, K.J.H., Sargent, L.D., Williams, N.S.G., & Johnson, K.A. (2015) "40-second green roof views sustain attention: The role of micro-breaks in attention restoration, *J. Environ. Psychol., 42(*215), 182–189.

Lehr, C.A., Johnson, D.R., Bremer, C.D., Cosio, A.,Thompson, M. (2004). Increasing Rates of School Completion: Moving from Policy and Research to Practice. National Center on Secondary Education and Transition. Full Report.

Li, D. & Sullivan, W.C. (2016). Impact of views to school landscapes on recovery from stress and mental fatigue. *Landscape and Urban Planning, 148,* 149–158. http://dx.doi.org/10.1016/j.landurbplan.2015.12.015

Lupien, S.J., McEwen, B.S., Gunnar, M.R. & Heim, C. (2009). Effects of stress throughout the lifespan on the brain, behaviour and cognition. *Nature Reviews: Neuroscience, 10.* doi:10.1038/nrn2639.

Matsuoka, R.H. (2010). Student performance and high school landscapes: Examining the links. *Landscape and Urban Planning, 97*(4), 273–282. doi:10.1016/j.landurbplan.2010.06.011

McEwen, B.S. (2011). Effects of stress on the developing brain. *Cerebrum: the Dana forum on brain science, 14.* PMC3574783

Moeller, J., Brackett, M.A., Ivcevic, Z. & White, A.E. (2020). High school students' feelings: Discoveries from a large national survey and an experience sampling study. Learning and Instruction, 66, 101301. https://doi.org/10.1016/j.learninstruc.2019.101301.

North American Association for Environmental Education (NAAEE). (2017). Nature preschools and forest kindergartens: 2017 national survey. Washington, DC: NAAEE.

OECD. (2018). PISA 2015 Results in focus. Programme for International Students Assessment (PISA), Organisation for Economic Co-operation and Development. https://www.oecd.org/pisa/pisa-2015-results-in-focus.pdf

EDUCATION (CONT.)

OECD. (2019). Results from PISA 2018: United States. Country Note, Vol. I–III. Programme for International Student Assessment (PISA), Organisation for Economic Co-operation and Development. https://www.oecd.org/pisa/publications/PISA2018_CN_USA.pdf

PISA. (2015). PISA 2015 Results in focus. Organisation for Economic Co-operation and Development.

Shu, S. & Ma, H. (2019). Restorative Effects of Classroom Soundscapes on Children's Cognitive Performance. *International Journal of Environmental Research & Public Health, 16*(2), 293. https://doi.org/10.3390/ijerph16020293

Stanford University. (n.d.). Windhover: About. Retrieved February 3, 2021, from https://windhover.stanford.edu/about-0

Taylor, A. & Kuo, F.E. (2009). Children with attention deficits concentrate better after walk in the park. *Journal of Attention Disorders, 12*(5), 402–409. DOI: 10.1177/1087054708323000

U.S. Department of Education. (2017). The Condition of Education 2017 (NCES 2017-144). National Center for Education Statistics. Public School Expenditures. https://nces.ed.gov/fastfacts/display.asp?id=66

U.S. Department of Education. (2021, May). Public High School Graduation Rates, Annual Report. National Center for Education Statistics. Retrieved May 24, 2021, from https://nces.ed.gov/programs/coe/indicator/coi

van den Bogerd, N., Dijkstra, S.C., Tanja-Dijkstra, K., de Boer, M.R., Seidell, J.C., Koole, S.L. & Maas, J. (2020). Greening the classroom: Three field experiments on the effects of indoor nature on students' attention, well-being, and perceived environmental quality. *Building & Environment, 171,* 106675. https://doi.org/10.1016/j.buildenv.2020.106675

Wells, N.M., Myers, B.M., Todd, L.E., Barale, K., Gaolach, B., Ferenz, G., Aitken, M., Henderson, C.R., Tse, C., Pattison, K.O., Taylor, C., Connerly, L., Carson, J.B., Gensemer, A.Z., Franz, N.K. & Falk, E. (2015). The Effects of School Gardens on Children's Science Knowledge: A randomized controlled trial of low-income elementary schools. *International Journal of Science Education, 37*(17), 1464–5289. http://dx.doi.org/10.1080/09500693.2015.1112048

Williams, D.R. & Dixon, P.S. (2013). Impact of Garden-Based Learning on Academic Outcomes in Schools: Synthesis of Research Between 1990 and 2010. *Review of Educational Research, 83*(2), 211–235. DOI: 10.3102/0034654313475824

Wu, C., McNeely, E., Ceden o-Laurent, J.G., Pan, W., Adamkiewicz, G., Dominici, F., Lung, S.C., Su, H. & Spengler, J.D. (2014). Linking student performance in Massachusetts elementary schools with the "greenness" of school surroundings using remote sensing. *PLoS ONE, 9*(10), e108548. doi:10.1371/journal.pone.0108548

Ch4. HEALTHCARE

American Hospital Association. (2022). Fast Facts on US Hospitals 2022. Retrieved on 4 October 2022 from https://www.aha.org/statistics/fast-facts-us-hospitals

American Psychological Association. (2006). Stress Weakens the Immune System. American Psychological Association. Retrieved May 23, 2021, from https://www.apa.org/research/action/immune

Andel, C., Davidow, S.L., Hollander, M., & Moreno, D.A. (2012). The economics of health care quality and medical errors. *Journal of Health Care Finance, 39*(1), 39-50.

Bai, G., & Anderson, G.F. (2016). A More Detailed Understanding Of Factors Associated With Hospital Profitability. *Health Affairs, 35*(5), 889–897. doi: 10.1377/hlthaff.2015.1193

Barnes, M., Oner, N., Ray, M.N., & Zengul, F.D. (2017). Exploring the Association between Quality and Financial Performance in U.S. Hospitals: A Systematic Review. *Journal of Health Care Finance, 44*(2).

Beauvais, B. Richter, J.P., Kim, F.S., Sickels, G., Hook, T., Kiley, S., & Horal, T. (2019). Does Patient Safety Pay? Evaluating the Association Between Surgical Care Improvement Project Performance and Hospital Profitability. Journal of Healthcare Management, 64(3), 142–154. doi.org/10.1097/JHM-D-17-00208

Brewer, B.W., & Karoly, P. (1989). Effects of attentional focusing on pain perception. Motivation & Emotion, 13, 193–203. https://doi.org/10.1007/BF00995535

Center for Medicare and Medicaid Services (CMS). (2019). National Health Expenditure Data: Historical. Retrieved May 24, 2021, from https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/NationalHealthExpendData/NationalHealthAccountsHistorical

Center for Medicare and Medicaid Services. (2021). Hospital Value-based Purchasing Program. Center for Medicare and Medicaid Services. CMS.gov. Retrieved May 24, 2021, from https://www.cms.gov/Medicare/Quality-Initiatives-Patient-Assessment-Instruments/HospitalQualityInits/Hospital-Value-Based-Purchasing-

Chiu, W.C., Chang, P.S., Hsieh, C.F., Chao, C.M., & Lai, C.C. (2017). The impact of windows on the outcomes of medical intensive care unit patients. *International Journal of Gerontology, 12*(1), 67–70. 10.1016/j.ijge.2017.06.002.

Cooper Marcus, C., & Sachs, N.A. (2014). *Therapeutic landscapes: An evidence-based approach to designing healing gardens and restorative outdoor spaces.* Hoboken, NJ: John Wiley and Sons. 978-1118231913.

Cooper Marcus, C., & Barnes, M. (1995). "Gardens in Healthcare Facilities: Uses, Therapeutic Benefits, and Design Recommendation." University of California at Berkeley. The Center for Health Design.

HEALTHCARE (CONT.)

Cordoza, M., Ulrich, R.S., Manulik, B.J., Gardiner, S.K., Fitzpatrick, P.S., Hazen, T.M., Alar Mirka, R. & Perkins, S. (2018). Impact of Nurses Taking Daily Work Breaks in a Hospital Garden on Burnout. *Am J Crit Care, 27*(6):508–512. doi: 10.4037/ajcc2018131

Daly, R. (2019, October 1). Hospitals innovate to control labor costs. Healthcare Financial Management Association. Retrieved February 10, 2021, from https://www.hfma.org/topics/hfm/2019/october/hospitals-innovate-to-control-labor-costs.html

Domke, H. (2008). Healing Gardens. Henry Domke Fine Art. Interview with Naomi Sachs. Web. http://henrydomke.com/blog/2008/05/09/whats-new-with/

Ellison, A. (2019). Average hospital expenses per inpatient day across 50 states. Becker's Hospital Review. Retrieved April 14, 2021, from https://www.beckershospitalreview.com/finance/average-hospital-expenses-per-inpatient-day-across-50-states.html

Freeman, W.J., Weiss, A.J., & Heslin, K.C. (2018). Overview of U.S. Hospital Stays in 2016: Variation by Geographic Region. Agency for Healthcare Research & Quality. https://www.hcup-us.ahrq.gov/reports/statbriefs/sb246-Geographic-Variation-Hospital-Stays.jsp

Hall, L.M.G. (2005). *Quality Work Environments For Nurse And Patient Safety*. Sudbury, Mass.; Toronto: Jones And Bartlett Pub.

Healthstream. (2017). To Improve Healthcare Quality Outcomes, We Must Focus on Turnover. Healthcare Management & Administration Blog. Retrieved June 3, 2021, from https://www.healthstream.com/resources/blog/blog/2017/10/11/to-improve-healthcare-quality-outcomes-we-must-focus-on-turnover

Joarder, A.R. & Price, A.D.F. (2013). Impact of daylight illumination on reducing patient length of stay in hospital after coronary artery bypass graft surgery. *Lighting Research & Technology, 45,* 439–441. https://doi.org/10.1177/1477153512455940

Kellert, S.R., Heerwagen, J., & Mador, M. (2008). *Biophilic Design: The Theory, Science and Practice of Bringing Buildings to Life*. Wiley: New Jersey.

Kiecolt-Glaser, J.K., Marucha, P.T., Malarkey, W.B., Mercado, A.M., & Glaser, R. (1995). Slowing of wound healing by psychological stress. *The Lancet, 346*(8984), 1194–1196. https://doi.org/10.1016/S0140-6736(95)92899-5.

Koechlin, F., Lorenzoni, L., & Schreyer, P. (2010). Comparing Price Levels of Hospital Services Across Countries: Results of Pilot Study. OECD Health Working Papers, No. 53, OECD Publishing, Paris, https://doi.org/10.1787/5km91p4f3rzw-en.

Paraskevopoulou, A.T., & Kamperi, E. (2018). Design of hospital healing gardens linked to pre- or post-occupancy research findings. *Frontiers of Architectural Research, 7,* 395–414. https://doi.org/10.1016/j.foar.2018.05.004

Park, S.H., & Mattson, R.H. (2008). Effects of Flowering and Foliage Plants in Hospital Rooms on Patients Recovering from Abdominal Surgery. *HortTechnology, 18*(4), 563–568. DOI:10.21273/HORTTECH.18.4.563

Park, S.H., & Mattson, R.H. (2009). therapeutic influences of plants in hospital rooms on surgical recovery. *Horticultural Science, 44*(1), 102–105. https://doi.org/10.21273/HORTSCI.44.1.102

Pati, D., Harvey, T.E., & Barach, P. (2008). Relationships between exterior views and nurse stress: an exploratory examination. *Health Environments Research & Design, 1*(2), 27–38. doi: 10.1177/193758670800100204.

Pati, D., Freier, P., O'Boyle, M., Amor, C., & Valipoor, S. (2015). The Impact of Simulated Nature on Patient Outcomes: A Study of Photographic Sky Compositions. *Health Environments Research & Design Journal, 9*(2), 36–51. https://doi.org/10.1177/1937586715595505

Putrino, D., Ripp, J., Herrera, J.E., Mortes, M., Kellner, C., Rizk, D., & Dams-O'Connor, K. (2020). Multisensory, Nature-Inspired Recharge Rooms Yield Short-Term Reductions in Perceived Stress Among Frontline Healthcare Workers. *Front. Psychol.,* 19 November 2020, Sec. Psychology for Clinical Settings https://doi.org/10.3389/fpsyg.2020.560833

Richter, J.P. & Muhlestein, D.P. (2017). Patient experience and hospital profitability: Is there a link?. *Health Care Management Review, 42*(3), 247–257. DOI:10.1097/HMR.0000000000000105

Rust, R.T., Zahorik, A.J., & Keiningham, T.L. (1995). Return on quality (ROQ): Making service quality financially accountable. *The Journal of Marketing, 59*(2), 58–70. https://doi.org/10.1177/002224299505900205

Sadler, B.L., DuBose, J.R., Malone, E.B., & Zimring, C.M. (2008). "Healthcare Leadership: The Business Case for Building Better Hospitals through Evidence Based Design." Georgia Institute of Technology, The Center for Health Design.

Segerstrom, S.C., & Miller, G.E. (2004). Psychological Stress and the Human Immune System: A Meta-Analytic Study of 30 Years of Inquiry. *Psychological Bulletin, 130*(4). 601–630. https://dx.doi.org/10.1037%2F0033-2909.130.4.601

Shepley, M.M., Gerbi, R.P., Watson, A.E., Imgrund, S., & Sagha-Zadeh, R. (2012). The impact of daylight and views on ICU patients and staff. *Health Environments Research & Design, 5*(2):46–60. doi: 10.1177/193758671200500205.

Swann, J.E., Richardson, L.E., & Hutton, J.D. (2003). Do Appealing Hospital Rooms Increase Patient Evaluations of Physicians, Nurses, and Hospital Services?. *Health Care Management Review, 28*(3), 254–264. DOI:10.1097/00004010-200307000-00006

Wilson, Larkin M. (1972). Intensive Care Delirium: The Effect of Outside Deprivation in a Windowless Unit. *Arch Intern Med., 130*(2): 225–226. doi:10.1001/archinte.1972.03650020055010

Ulrich, R.S. (1984). View through a window may influence recovery from surgery. *Science, 224*(4647), 410–411. doi: 10.1126/science.6143402

Ulrich, R.S. (1999). "Effects of Garden on Health Outcomes: Theory and Research." Chapter in C. Maruc and M. Barnes (Eds.), *Healing Gardens*. New York, Wiley, 27–86.

Ulrich, R.S., Zimring, C., Quan, X., & Joseph, A. (2006). The environment's impact on stress. In S. Marberry (ed.), *Improving healthcare with better building design*. Chicago: Health Administration Press, pp. 37–61.

HEALTHCARE (CONT.)

Vincent, E., Batiisto, D., Grimes, L., & McCubbin, J. (2010). The Effects of Nature Images on Pain in a Simulated Hospital Patient Room. *Health Environments Research & Design Journal, 3*(3), 42-55. doi: 10.1177/193758671000300306.

APPENDIX A

Watts, G., Khan, A., & Pheasant, R. (2016). Influence of soundscape and interior design on anxiety and perceived tranquility of patients in a healthcare facility. *Applied Acoustics, 104*, 135–141.

APPENDIX B1

AHA. (2021). Fast Facts on U.S. Hospitals, 2021. American Hospital Association. Retrieved May 23, 2021, from https://www.aha.org/statistics/fast-facts-us-hospitals

OECD. (2021). Length of hospital stay (indicator). doi: 10.1787/8dda6b7a-en (Accessed on 29 June 2021). https://data.oecd.org/healthcare/length-of-hospital-stay.htm

Ch5. RETAIL

Ali, F. (2021). US ecommerce grows 44.0% in 2020. Digital Commerce 360. https://www.digitalcommerce360.com/article/us-ecommerce-sales/

Bagozzi, R.P., Gopinath, M., & Nyer, P.U. (1999). The role of emotions in marketing. *Journal of the Academy of Marketing Science, 27*, 184–206. doi:10.1177/0092070399272005

Brengman, M., Willems, K. & Joye, Y. (2012). Impact of in-store greenery on customers. *Psychology and Marketing, 29*(11), 807-821. https://doi.org/10.1002/mar.20566

Briedis, H., Kronschnabl, A., Rodriguez, A., & Ungerman, K. (2020). Adapting to the next normal in retail: The customer experience imperative. McKinsey & Company. https://www.mckinsey.com/industries/retail/our-insights/adapting-to-the-next-normal-in-retail-the-customer-experience-imperative#

Buber, R., Ruso, B., Gardner, J., Atzwanger, K. & Gruer, S. (2007). Evolutionary Store Design. How Water, Plants, Animals and Sight Protection Affect Consumer Behaviour. Proceedings of the Conference of the Australian & New Zealand Marketing Academy.

Donovan, R. J., & Rossiter, J. R. (1982). Store atmosphere: An environmental psychology approach. *Journal of Retailing, 58*, 34–57.

Emig, T. (n.d.). What is a Public Market? Boston Public Market. Retrieved April 18, 2021, from https://bostonpublicmarket.org/blog/322/what-is-a-public-market/

Grand Turkish Bazaar. (2018, January 22). History of the Grand Bazaar Istanbul. Grand Turkish Bazaar. Retrieved April 19, 2021, from https://www.grandturkishbazaar.com/history-of-the-grand-bazaar-istanbul/

Harrell, Eben (2019). Neuromarketing: What You Need to Know. Harvard Business Review, 23 January 2019, Consumer Behavior Sect. Last accessed 12 February 2023, from https://hbr.org/2019/01/neuromarketing-what-you-need-to-know

Heerwagen, J.H. (1998). "Design, Productivity and Well Being: What are the Links?" Presented at AIA Conference on Highly Effective Facilities. Cincinnati, OH.

Heschong, L. (1999) Skylighting and Retail Sales, An Investigation into the Relationship Between Daylighting and Human Performance, Pacific Gas & Electric Company

Joye, Y., Willems, K., Brengman, M., & Wolf, K. (2010). The effects of urban retail greenery on consumer experience: Reviewing the evidence from a restorative perspective. *Urban Forestry & Urban Greening, 9*, 57–64.

Kepron, D. (2014). Ch.9 "Please Me" and Ch.10 "Shopping: The Agony and Ecstasy". Retail (r)Evolution. ST Media Group International: Cincinnati, pp. 161–201. ISBN: 0944094732

Kotler, P. (1973). Atmosphere as a marketing tool. Journal of Retailing, 49, 48–64.

KPMG. (2018). Global Retail Trends 2018. KPMG Global Consumer & Retail team. https://home.kpmg/xx/en/home/insights/2018/03/2018-retail-trends.html

Lam, S.Y. (2001). The Effects of Store Environment on Shopping Behaviors: a Critical Review. *Advances in Consumer Research, 28*, 190–197.

Maxham, J.G., Netemeyer, R.G., & Lichtenstein, D.R. (2008). The Retail Value Chain: Linking Employee Perceptions to Employee Performance, Customer Evaluations, and Store Performance. *Marketing Science 27*(2), 147–167. http://dx.doi.org/10.1287/mksc.1070.0282

Brendan O'Grady (November 10, 2016). Seeing Green: Biophilia and Retail are a Natural Fit. "You Are Here", Callison RTKL. Last accessed February 14, 2023, from https://www.callisonrtkl.com/you-are-here-archive/seeing-green-biophilia-and-retail-are-a-natural-fit/

Ortégon-Cortázar, L. & Royo-Vela, M. (2019). Effects of the biophilic atmosphere on intention to visit: the affective states' mediating role. *Journal of Services Marketing, 33*, 168–180. DOI 10.1108/JSM-01-2018-0019

Perdikaki, O. Kesavan, S., & Swaminathan, J.M. (2012). Effect of Traffic on Sales and Conversion Rates of Retail Stores. *Manufacturing & Service Operations Management, 14*(1), 145–162. http://dx.doi.org/10.1287/msom.1110.0356

Romm, J. & Browning, W. (1995) Greening the Building and the Bottom Line, Rocky Mountain Institute.

Rosenbaum, M.S., Ramirez, G.C., & Camino, J.R. (2018). A dose of nature and shopping: The restorative potential of biophilic lifestyle center designs. *Journal of Retailing and Consumer Services, 40*, 66–73.

Sherman, E., Mathur, A., & Smith, R.B. (1997). Store environment and consumer purchase behavior: Mediating role of consumer emotions. *Psychology & Marketing, 14*, 361–378.

RETAIL (CONT.)

Tifferet, S. & Vilnai-Yavetz, I. (2017). Phytophilia and service atmospherics: The effect of indoor plants on consumers. *Environment and Behavior, 49*(7) 814–844. DOI: 10.1177/0013916516669390

US Census Bureau. (2021). 2019 Annual retail trade survey. https://www.census.gov/data/tables/2019/econ/arts/annual-report.html

Vilnai-Yavetz, I. & Rafaeli, A. (2011). The effects of a service provider's messy appearance on customer reactions. Services *Marketing Quarterly, 32*, 161–180. doi :10.1080/15332969.2011.581890

Windhager, S., Atzwanger, K., Bookstein, F.L., & Schaefer, K. (2011). Fish in a mall aquarium—An ethological investigation of biophilia. *Landscape and Urban Planning, 99*, 23–30. doi:10.1016/j.landurbplan.2010.08.008

Wolf, K.L. (2003). Public response to the urban forest in inner-city business districts. *Journal of Arboriculture, 29*(3), 117–126.

Wolf, K.L. (2004). Nature in the Retail Environment: Comparing Consumer and Business Response to Urban Forest Conditions. *Landscape Journal, 23*, 1–4.

Wolf, K.L. (2005). "Trees in the small city retail business district: comparing resident and visitor perceptions." *Journal of Forestry 103*, 390–395.

Urban Land Institute. (2016). Cultivating Development: Trends and Opportunities at the Intersection of Food and Real Estate. Washington, D.C.: Urban Land Institute.

APPENDIX A

Rosenbaum, M.S., Ramirez, G.C. & Camino, J.R. (2018). A dose of nature and shopping: The restorative potential of biophilic lifestyle center designs. *Journal of Retailing and Consumer Services, 40*, 66–73.

APPENDIX B1

Womply. (n.d.). The State of Local Retail 2019. Womply.com. https://www.womply.com/state-of-local-retail-2019/

Ch6. HOSPITALITY

AARP (2016). AARP Reveals How Different Generations Take Their Vacations, AARP Press Room, Travel & Lifestyle, 16 January 2016, Last accessed 2 February 2022, https://press.aarp.org/2016-01-12-AARP-Reveals-How-Different-Generations-Take-Their-Vacations?cmp=RDRCT-e5807f7d-20200402#assets_all

Barkley & FutureCast (2016). The Millennial Brief on Travel & Lodging. Trends Report. Barkley Inc. & FutureCast LLC.

Berg, J. (2019). Spend the night with succulents, palms and ferns at the first plant pop-up hotel from Orbitz. PRNewswire Last accessed 13 October 2022, https://www.prnewswire.com/news-releases/spend-the-night-with-succulents-palms-and-ferns-at-the-first-plant-pop-up-hotel-from-orbitz-300918048.html

Browning, W., Francis, L., Macies, R., & Fisher, L. (2016). Human Spaces 2.0, Biophilic Design in Hospitality, Interface.

Condor Ferries. (2022). Hotel Industry Statistics & Trends 2020–2021. Last accessed 8 February 2022: https://www.condorferries.co.uk/hotel-industry-statistics

Durst, C.S., 2018. Defining the 2019 hotel lobby. Lodging Magazine. Retrieved 4 November 2019, https://lodgingmagazine.com/defining-the-2019-hotel-lobby/

Fox, J. (2017). 3 design trends for 2017, Hotel Management, 30 November 2017, Last accessed 2 February 2022. https://www.hotelmanagement.net/design/3-design-trends-for-2018

Frochot, I. & Kreziak, D. (2019). Home away from home: A longitudinal study of the holiday appropriation process, April 2019 Tourism Management. DOI:10.1016/j.tourman.2018.10.025

Gardner, M.P. (1985). Mood states and consumer behavior: a critical review. *Journal of Consumer Research, 12*(3), 281–300. https://doi.org/10.1086/208516

Gherini, A. (2018, October 31). Millennials Ignited The Experience Economy, Here Is How To Cash In. Inc.com. Retrieved on 2 February 2022, https://www.inc.com/anne-gherini/cash-in-on-experience-economy.html

GWI. (2018). Global Wellness Tourism Economy, Global Wellness Institute; in WTTC (Nov 2021). Trending in travel: Emerging consumer trends in Travel & Tourism in 2021 and beyond. p17, viewed September 2022, https://pages.trip.com/images/group-home/2021_Trending_in_Travel_EN.pdf

GWI. (2021). Wellness tourism. Global Wellness Institute. Last accessed 12 October 2022, https://globalwellnessinstitute.org/what-is-wellness/what-is-wellness-tourism/

Hartig, T., Evans, G.W., Jamner, L.D., Davis, D.S., & Gärling, T. (2003). Tracking restoration in natural and urban field settings. *J. Environ. Psychol., 23*(2), 109–123. https://doi.org/10.1016/S0272-4944(02)00109-3

Hartmann, P., Apaolaza, V., & Alija, P. (2013). Nature imagery in advertising. *International Journal of Advertising, 32*(2), 183–210. doi:10.2501/ija-32-2-183-210

Hyde, F.,(2021) "Multifamily Design Strategies Hoteliers Can Apply to Boost Curb Appeal" Hotel Executive (July 15, 2021) Last accessed 29 July 2021, https://www.hotelexecutive.com/business_review/5735/multifamily-design-strategies-hoteliers-can-apply-to-boost-curb-appeal

Lange, E., & Schaeffer, P.V. (2001). A comment on the market value of a room with a view. *Landscape and Urban Planning, 55*(2), 113–120. doi:10.1016/s0169-2046(01)00148-7

Lee, S.H. (2019). Effects of biophilic design on consumer responses in the lodging industry. *International Journal of Hospitality Management, 83,* 141–150. doi: 10.1016/j.ijhm.2019.05.006

HOSPITALITY (CONT.)

Mandelbaum, R. & McDade, G. (2017, February 21). The Rising Cost of Rooms, Lodging. Retrieved on 2 February 2022, https://lodgingmagazine.com/the-rising-cost-of-rooms/

Mandelbaum, R. (2020, October 13). Ancillary Revenue In 2020: Resorts Benefit the Most. CBRE Hotels Research. https://www.cbrehotels.com/en/research/articles/ancillary-revenue-in-2020-resorts-benefit-the-most

Manley, B. (2018, March 21). Hotel Owners Focus Renovations on Public Spaces, CoStar Group. Retrieved 27 July 2021, https://www.costar.com/article/2010011461/hotel-owners-focus-renovations-on-public-spaces

Masiero, L., Yang, Y., & Qiu, R.T.R. (2019). Understanding hotel location preference of customers: Comparing random utility and random regret decision rules. Tourism Management, 73, 83–93. doi:10.1016/j.tourman.2018.12.002

McMillin, D. (2019). First-Ever Plant Pop-Up Hotel Grows in Chicago, Convene, 23 October 2019, PCMA. Last viewed 13 October 2022, https://www.pcma.org/plant-pop-up-hotel-grows-chicago/

Nagy, C., 2018. Why the hotel lobby is the perfect antidote to Airbnb. Skift. Retrieved 1 December 2019, https://skift.com/2018/05/01/why-the-hotel-lobby-is-the-perfect-antidote-to-airbnb/

Nanua, L., Alib, F., Berezinac, K., & Cobanoglub, C. (2020). The effect of hotel lobby design on booking intentions: An intergenerational examination. International Journal of Hospitality Management, 89, https://doi.org/10.1016/j.ijhm.2020.102530

Orbitz. (n.d.) Plant Pop-Up Hotel. Orbitz, LLC. Last accessed 13 October 2022, https://www.orbitz.com/plantpopup

Oxford Economics (2019). Economic Impact of US Hotel Industry, Oxford Economics, study funded by Funded by the American Hotel & Lodging Association Educational Foundation.

Potter, E. (2021). Colour trends: A return to nature is calling, Hotel Designs. Last accessed 2 February 2022, https://hoteldesigns.net/industry-news/colour-trends-a-return-to-nature-is-calling/

Purani, K. & Kumar, D.S. (2018). Exploring restorative potential of biophilic servicescapes. *Journal of Services Marketing, 32*(4): 414–429. https://doi.org/10.1108/JSM-03-2017-0101

Riley, K.L. (2019). Doing the Right Thing: Why Hotels Are Embracing Biophilic Design, The Fat Plant Society. Last accessed September 2022, https://thefatplantsociety.medium.com/doing-the-right-thing-why-hotels-are-embracing-biophilic-design-6c28ddbbb445

Rosenbaum, M.S. (2009). Restorative service scapes: restoring directed attention in third places. In Purani, K. & Kumar, D.S. (2018). Exploring restorative potential of biophilic servicescapes. *Journal of Services Marketing*. https://doi.org/10.1108/JSM-03-2017-0101

Sperance, C. (2021, November 12). Accor's Lifestyle Ambition Shows Ancillary Revenue Isn't Just for Airlines. Skift. https://skift.com/2021/11/12/accors-lifestyle-ambition-shows-ancillary-revenue-isnt-just-for-airlines/

Sterkenberg, Z. (2017, September 22). Hotel Trends Transforming the Guest Experience: Part 1, ambius. Retrieved on 2 February 2022, https://www.ambius.com/blog/hotel-trends-transforming-the-guest-experience-part-1-macro-trends/

Tifferet, S., & Vilnai-Yavetz, I. (2017). Phytophilia and Service Atmospherics: The Effect of Indoor Plants on Consumers. *Environment and Behavior, 49*(7), 814–844. https://doi.org/10.1177/0013916516669390

Rocky Mountain Institute, Wilson, A., Uncapher, J. L., McManigal, L., Lovins, L. H., Cureton, M. & Browning, W. D. (1998). *Green Development, Integrating Ecology and Real Estate*. New York: John Wiley & Sons, Inc.

WTTC. (Nov 2021). Trending in travel: Emerging consumer trends in Travel & Tourism in 2021 and beyond. p17, viewed September 2022, https://pages.trip.com/images/group-home/2021_Trending_in_Travel_EN.pdf

Worsfold, K., Fisher, R., Mcphail, R., Francis, M., & Thomas, A. (2016). "Satisfaction, value and intention to return in hotels", *International Journal of Hospitality Management*, October 2016, doi: 10.1108/IJCHM-04-2015-0195

Yeung, O. & Johnston, K. (2018, November) "Global Wellness Tourism Economy," Global Wellness Institute. https://globalwellnessinstitute.org/wp-content/uploads/2018/11/GWI_GlobalWellnessTourismEconomyReport.pdf

Zemke, D.M.V., Raab, C., & Wu, K. (2018). "How does hotel design contribute to property performance?". *International Journal of Contemporary Hospitality Management, 30*(2), 919–938. ISSN: 0959-6119, https://doi.org/10.1108/IJCHM-06-2016-0330

Ch7. COMMUNITY

Appleseed Inc. (2015). The central park effect: Assessing the value of central park's contribution to New York City's economy. Appleseed Inc. Central Park Conservancy. https://assets.centralparknyc.org/pdfs/about/The_Central_Park_Effect.pdf

Brown, S.C., Lombard, J., Wang, K., Byrne, M.M., Toro, M., Pater-Zyberk, E., Feaster, D.J., Kardys, J., Nardi, M.I., Perez-Gomez, G., Pantin, H.M., & Szapocznik, J. (2016). Neighborhood Greenness and Chronic Health Conditions in Medicare Beneficiaries. *American Journal of Preventive Medicine, 51*(1), 78–89. https://doi.org/10.1016/j.amepre.2016.02.008

Burley, B.A. (2018). Green infrastructure and violence: Do new street trees mitigate violent crime?. *Health and Place, 54*, 43–49. https://doi.org/10.1016/j.healthplace.2018.08.015

COMMUNITY (CONT.)

Center for Disease Control and Prevention (2016). Health, United States, 2017: Table 57. Participation in leisure-time aerobic and muscle-strengthening activities that meet the federal 2008 Physical Activity Guidelines for Americans among adults aged 18 and over, by selected characteristics: United States, selected years 1998–2016. National Center for Health Statistics.

Center for Disease Control and Prevention. (2021). National Center for Chronic Disease Prevention and Health Promotion (NCCDPHP). Retrieved on February 3, 2021 from https://www.cdc.gov/chronicdisease/index.htm

Chicago Police Department (2023) CompStat-Public 2022 Year End., accessed 10 May 2023, https://home.chicagopolice.org/wp-content/uploads/CompStat-Public-2022-Year-End-1.pdf

City of Portland Environmental Services (n.d.). Tree Program: Treebate runs from September 1 through April 30. https://www.portlandoregon.gov/bes/51399 (last accessed July 21, 2021)

Claxton, G., Sawyer, B., & Cox, C. (2019). How affordability of health care varies by income among people with employer coverage. Peterson Center on Healthcare & Kaiser Family Foundation. Peterson-KFF Health System Tracker. https://www.healthsystemtracker.org/brief/how-affordability-of-health-care-varies-by-income-among-people-with-employer-coverage/#item-start

Cohen, M.A. & Piquero, A.R. (2009). New Evidence on the Monetary Value of Saving a High Risk Youth. *Journal of Quantitative Criminology, 25*(1), 25–49.

Correll, M.R., Lillydahl, J.H., & Singell, L.D. (1978). The Effect of Greenbelts on Residential Property Values: Some Findings on the Political Economy of Open Space. *Land Economics, 54*(2), 207–217.

Crompton, J.L. (2001). The Impact of Parks on Property Values: A Review of the Empirical Evidence. *Journal of Leisure Research, 33*(1), 1–31.

Daigneau, E. (2018). Green Roof Requirements Are On the Rise. Governing: The Future of States and Localities. https://www.governing.com/archive/gov-green-roofs.html

Davis, L.M., Bozick, R., Steele, J. L., Saunders, J., & Miles, J N. V. (2013) Evaluating the Effectiveness of Correctional Education, Rand Corporation and the US Department of Justice Bureau of Justice Assistance, https://bja.ojp.gov/sites/g/files/xyckuh186/files/Publications/RAND_Correctional-Education-Meta-Analysis.pdf

Deng, J., Arano, K.G., Pierskalla, C., & McNeel, J. (2010). Linking urban forests and urban tourism: A case of Savannah, Georgia. *Tourism Analysis, 15*(2), 167–181. DOI: 10.3727/108354210X12724863327641

de Vries, S., Verheij, R. A., Groenewegen, P. P., & Spreeuwenberg, P. (2003). Natural environments - healthy environments? An exploratory analysis of the relationship between greenspace and health. *Environment and Planning A, 35*(10), 1717-1731. https://doi.org/10.1068/a35111

Donovan, G.H. & Butry, D.T. (2010). Trees in the city: Valuing street trees in Portland, Oregon. *Landscape and Urban Planning, 94,* 77–83. https://doi.org/10.1016/j.andurbplan.2009.07.019

Fido, D. & Richardson, M. (2019). Empathy Mediates the Relationship Between Nature Connectedness and Both Callous and Uncaring Traits. *Ecopsychology, 11*(2). DOI: 10.1089/eco.2018.0071

Gerteis, J., Izrael, D., Deitz, D., Leroy, L., Ricciardi, R., Miller, T., & Basu, J. (2014). Multiple Chronic Conditions Chartbook 2010 Medical Expenditure Panel Survey Data. Rockville, MD: Agency for Healthcare Research and Quality.https://www.ahrq.gov/sites/default/files/wysiwyg/professionals/prevention-chronic-care/decision/mcc/mccchartbook.pdf

Giles-Corti, B., Broomhall, M.H., Knuiman, M.,Collins, C., Douglas, K., Ng, K., Lange, A., & R.J. Donovan (2005). Increasing Walking: How Important is Distance to, Attractiveness, and Size of Public Open Space?. *American Journal of Preventive Medicine, 28*, 169–176.

Gilstad-Hayden, K., Wallace, L.R., Carroll-Scott, A., Meyer, S.R., Barbo, S., Murphy-Dunning, C., & Ickovics, J.R. (2015). Research note: Greater tree canopy cover is associated with lower rates of both violent and property crime in New Haven, CT. *Landscape and Urban Planning, 143,* 248–253. https://doi.org/10.1016/j.landurbplan.2015.08.005

Grimm, A. (2022) What would it cost to reduce crime in Chicago? Chicago Sun Times, Apr 21, 2022, 8:24pm EDT https://chicago.suntimes.com/crime/2022/4/21/23026049/what-cost-cut-crime-non-violence-police-cpd-alternative-cred

Harnik, P. & Welle, B. (2009). Measuring the Economic Value of a City Park System. The Trust for Public Land. Washington, D.C.

Heaton, P. (2010). Hidden in plain sight: What cost-of-crime research can tell us about investing in police. Rand Corporation Center on Quality Policing. https://www.rand.org/pubs/occasional_papers/OP279.html

Immergluck, D. (2023) unpublished presentation made as part of the Biophilic Cities Panel on Eco-Gentrification, Biophilic Leadership Summit 2023, Serenbe, GA.

John Hopkins Medicine (n.d.). Health Library: Risks of Physical Inactivity. https://www.hopkinsmedicine.org/healthlibrary/conditions/cardiovascular_diseases/risks_of_physical_inactivity_85,p00218

Kardan, O., Gozdyra, P., Misic, B., Moola, F., Palmer, L.J., Paus, T., & Berman, M.G. (2015). Neighborhood greenspace and health in a large urban center. *Nature, scientific report 5*; article 11610. doi:10.1038/srep11610

Kuo, F.E., Sullivan, W.C., Coley, R.L., & Brunson, L. (1998). Fertile Ground for Community: Inner-City Neighborhood Common Spaces. *American Journal of Community Psychology, 26*(6), 823–851. DOI: 10.1023/A:1022294028903

Kuo, F.E. & Sullivan, W.C. (2001a). Aggression and Violence in the Inner City: Effects of Environment via Mental Fatigue. *Environment and Behavior, 33*(4), 543–571. Sage Publications.

Kuo, F.E. & Sullivan, W.C. (2001b). Environment and Crime in the Inner City: Does Vegetation Reduce Crime?. *Environment and Behavior, 33*(3), 343–367. Sage Publications.

Levere, M. (2014). The High Line park and timing of capitalization of public goods. Department of Economics, University of California San Diego. Retrieved from http://docplayer.net/42473681-The-high-line-park-and-timing-of-capitalization-of-public-goods.html

Maas, J., Verheij, R.A., Groenewegen, P.P., de Bries, S., & Spreeuwenberg, P. (2006). Green space, urbanity, and health: how strong is the relation?. *Journal of Epidemiology & Community Health, 60*(7), 587–592. http://dx.doi.org/10.1136/jech.2005.043125

Majumdar, S., Deng, J., Zhang, Y., & Pierskalla, C. (2011). Using contingent valuation to estimate the willingness of tourists to pay for urban forests: A study in Savannah, Georgia. *Urban Forestry & Urban Greening, 10,* 275–280. https://doi.org/10.1016/j.ufug.2011.07.006

Metz, A.L. (2017). Back to Nature: The Relationship Between Nature Relatedness on Empathy and Narcissism in the Millennial Generation. *Educational Specialist, 65.* https://commons.lib.jmu.edu/edspec201019/65

Morales, D.J., Boyce, B.N., & Favretti, R.J. (1976). The Contribution of Trees to Residential Property Value: Manchester, Connecticut. *Valuation 23*(2), 26–43.

Nieuwenhuijsen, M.J., Davdand, P., Márquez, S., Bartoll, X., Barboza, E.P., Cirach, M., Borrell, C., & Zijlema, W.L. (2022). The evaluation of the 3-30-300 green space rule and mental health. *Environmental Research, 215*(2), 114387, https://doi.org/10.1016/j.envres.2022.114387

Peen, J., Schoevers, R.A., Beekman, A.T., & Dekker, J. (2010). The current status of urban-rural differences in psychiatric disorders. *Acta Psychiatrica Scandinavica, 121*, 84–93. DOI: 10.1111/j.1600-0447.2009.01438

Portland Parks & Recreation (2017). Tree Canopy Monitoring: Protocol and Monitoring from 2000-2015. https://www.portland.gov/sites/default/files/2020-08/tree-canopy-monitoring-2015.pdf (last accessed July 19, 2021)

Public First. (2021, December). Urban patriotism: The roles of civic identity in our cities' past, present and future. Opinion research for Landsec. Retrieved from https://landsec.com/sites/default/files/2022-01/Urban%20patriotism%20report.pdf

Shapiro, R.J. & Hassett, K.A. (2012). The economic benefit of reducing violent crime: A case study of 8 American cities. Center for American Progress. https://cdn.americanprogress.org/wp-content/uploads/issues/2012/06/pdf/violent_crime.pdf

Trust for Public Land. (2018, August 22). Here's the dirt on park trends: community gardens are growing. https://www.tpl.org/blog/here%E2%80%99s-dirt-park-trends-community-gardens-are-growing

Tikkanen, R. & Abrams, M.K. (2020). U.S. Health Care from a Global Perspective, 2019: Higher Spending, Worse Outcomes?. *The Commonwealth Fund.* https://www.commonwealthfund.org/publications/issue-briefs/2020/jan/us-health-care-global-perspective-2019

Tilt, J.H., Unfried, T.M., & Roca, B. (2007). Using Objective and Subjective Measures of Neighborhood Greenness and Accessible Destinations for Understanding Walking Trips and BMI in Seattle, Washington. *American Journal of Health Promotion, 21*(4), 371–379.

Troy, A., Grove, J.M., & O'Neil-Dunne, J. (2012). The relationship between tree canopy and crime rates across an urban–rural gradient in the greater Baltimore region. *Landscape and Urban Planning, 106*(3), 262–270. https://doi.org/10.1016/j.landurbplan.2012.03.010

United Nations. (2018). World Urbanization Prospects: The 2018 Revision. https://population.un.org/wup/Publications/Files/WUP2018-KeyFacts.pdf

U.S. Bureau of Labor Statistics (2018). Consumer Expenditure Survey, September, 2018: Table 1110. Deciles of income before taxes: Annual expenditure means, shares, standard errors, and coefficients of variation. United States Department of Labor. Washington, DC. https://www.bls.gov/cex/2017/combined/decile.pdf

Van der Wahl, A.J., Schade, H.M., Krabbendam, L., & van Vugt, M. (2013). Do natural landscapes reduce future discounting in humans?. Proceedings of the Royal Society, 280. https://doi.org/10.1098/rspb.2013.2295

Voicu, I. & Been, V. (2008). The effect of community gardens on neighboring property values. *Real Estate Economics, 36*(2), 241–283.

Weinstein, N., Przybylski, A.K., & Ryan, R.M. (2009). Can Nature Make Us More Caring? Effects of Immersion in Nature on Intrinsic Aspirations and Generosity. *Journal of Personality and Social Psychology, 84*, 960–971.

Wolf, K.L. (2010). Community Economics - A Literature Review. Green Cities: Good Health. College of the Environment, University of Washington. https://depts.washington.edu/hhwb/Print_Economics.html

World Health Organization (2008). Physical Inactivity: A Global Public Health Problem. https://www.who.int/dietphysicalactivity/factsheet_inactivity/en/

World Health Organization Regional Office for Europe (2016). Urban green spaces and health. https://www.euro.who.int/en/health-topics/environment-and-health/urban-health/publications/2016/urban-green-spaces-and-health-a-review-of-evidence-2016

Zelenski, J.M., Doplo, R.L., & Capaldi, C.A. (2015). Cooperation is in our nature: Nature exposure may promote cooperative and environmentally sustainable behavior. *J. Environ. Psychol., 42*, 24–31. https://doi.org/10.1016/j.jenvp.2015.01.005

GOING FORWARD WITH BIOPHILIC DESIGN

Austin Gray, W., A. Loder, & S. Timm (2021). Global Research Agenda: Health well-being and the built environment. International Well Building Institute, January, 2021; p. 31. Last accessed 9 January 2023 from https://marketing.wellcertified.com/global-research-agenda

BIOPHILIA PUBLICATIONS BY TERRAPIN

These publications and others can be accessed with these links or from Terrapin Bright Green's website: www.terrapinbg.com/publications

The Nature of Wood
An exploration of the science on biophilic responses to wood

Working with Fractals
A resource for practitioners of biophilic design

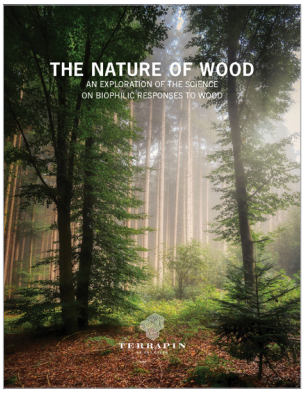
Nature Inside
A Biophilic Design Guide (RIBA Publishing, 2020)

14 Patterns of Biophilic Design
Improving Health and Well-Being in the Built Environment

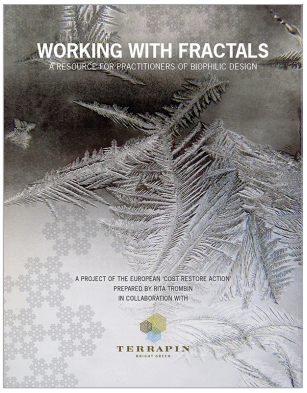
The Nature of Air
Economic & Bio-Inspired Perspectives on Indoor Air Quality Management

An Ear for Nature
Psychoacoustic Strategies for Workplace Distractions & The Bottom Line

Human Spaces 2.0
Biophilic Design in Hospitality



© 2022 Terrapin Bright Green



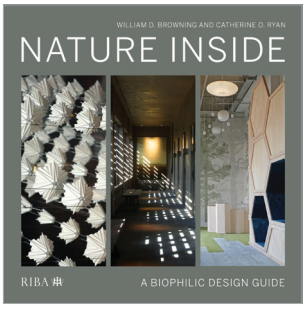
© 2021 Terrapin Bright Green

OTHER PUBLICATIONS BY TERRAPIN

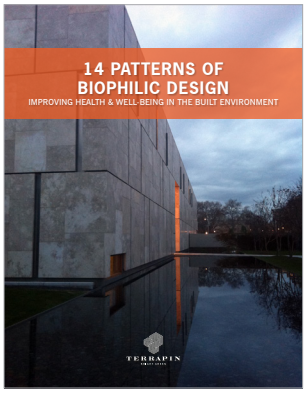
Malibu Rebuilder Guide
Recommendations for a Fire-Resilient, Resource-Efficient & Affordable New Home

Midcentury (Un)Modern
An Environmental Analysis of the 1958–73 Manhattan Office Building

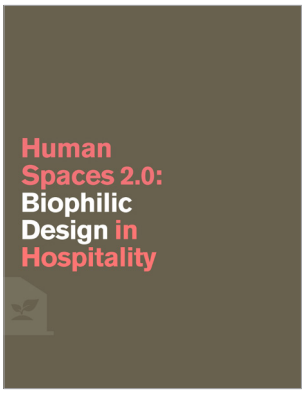
Tapping Into Nature
The Future of Energy, Innovation & Business



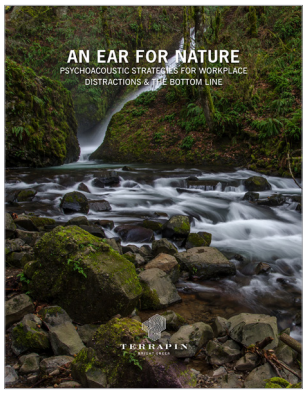
© 2020 RIBA Publishing



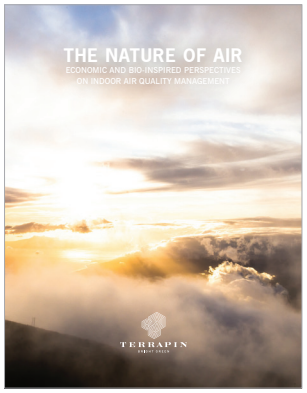
© 2014 Terrapin Bright Green



© 2016 Interface



© 2018 Terrapin Bright Green



© 2019 Terrapin Bright Green



TERRAPIN

BRIGHT GREEN