Future City 17

Chiara Catalano · Maria Beatrice Andreucci
Riccardo Guarino · Francesca Bretzel
Manfredi Leone · Salvatore Pasta *Editors*

Urban Services to Ecosystems

Green Infrastructure Benefits from the Landscape to the Urban Scale

Springer

Future City

Volume 17

Future City Description

As of 2008, for the first time in human history, half of the world's population now live in cities. And with concerns about issues such as climate change, energy supply and environmental health receiving increasing political attention, interest in the sustainable development of our future cities has grown dramatically.

Yet despite a wealth of literature on green architecture, evidence-based design and sustainable planning, only a fraction of the current literature successfully integrates the necessary theory and practice from across the full range of relevant disciplines.

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ISSN 1876-0899 ISSN 1876-0880 (electronic)
ISBN 978-3-030-75928-5 ISBN 978-3-030-75929-2 (eBook)
https://doi.org/10.1007/978-3-030-75929-2

Cover illustration: Zurich-Irchel University Campus, 10 May 2017, Deborah Hasler, Green Space Development Research Group, Institute for Natural Resources Science (IUNR), Zurich University of Applied Science (ZHAW)

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

The idea of editing this book arose during the 60th *Symposium of the International Association for Vegetation Science* (IAVS) held in Palermo from the 20th to the 24th June 2017, entitled *Vegetation Patterns in Natural and Cultural Landscapes*.

Initially, the book was meant to collect the contributions of the session *Green Infrastructure and Vegetation Science*, chaired by Riccardo Guarino (editor of this book and organizer of the mentioned IAVS symposium) for the Future City series. The proposal came from Springer, in recognition of the novel and multidisciplinary approaches presented at the session, in which a broad-ranging concept of GI was adopted, from regional ecological networks to urban green roofs, designed as stepping-stones for natural ecosystems.

However, after some reflection, the editors agreed that the book would have lacked its main purpose if it had been open only to scholars of vegetation ecology and related disciplines, in the domain of natural sciences. In fact, the concept of green infrastructure was originally coined in the context of territorial planning and urban design, and responds to the specific aim of ensuring accessibility to a wide range of nature's contributions to people, through a strategically planned network of natural and semi-natural areas, which interpenetrate widely the places where most people live their daily lives.

Therefore, the editors decided to contact and involve other scientists/practitioners, not necessarily having a background in vegetation ecology, namely architects, landscape architects and agronomists. The final book counts 26 contributions and involves 75 authors from 14 countries. All the chapters were blind peer reviewed by the editors as well as by independent parties.

It is still early to say whether this experiment of cultural integration has been successful, but we can already say that the experience of editing this book has been very stimulating, collaborative and truly transdisciplinary. It is hoped that the contributions included in this book will help readers overcome the cultural barriers that lead, at one extreme, to considering the vegetation of green infrastructure as a motionless and indistinct construction material and, at the other extreme, as elements of the natural world that do not need human intervention to continue to exist, thrive and spread.

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Acknowledgements

We thank Dr Valeria Rinaudo, publishing Editor at Springer, who approached us at the IAVS Symposium in 2017 and solicited us to initiate the present editorial project for the Future City Series. The session Green Infrastructure and Vegetation Science organised at the mentioned Symposium was indeed a great opportunity to start the fruitful exchange among vegetation scientists, foresters, agronomists and designers operating in the green infrastructure sector, which eventually developed into this book.

We thank Prof. Luigi Badalucco and Prof. Bruno Massa from SAAF (Scienze Agrarie, Alimentari e Forestali Department of the University of Palermo, Italy), Mr. Gary Grant from Green Infrastructure Consultancy Ltd. (London, UK), Dr Michael Nobis from WSL (Swiss Federal Research Institute, Birmensdorf, Switzerland), and Dr Patrice Prunier from HEPIA (Haute École du Paysage d'Ingénierie et d'Architecture, Jussy, Switzerland) for their helpful comments and constructive remarks while revising some of the chapters.

We hope that this book might enhance the opportunities for scientists and practitioners to cooperate, merging ecological principles into the designing of Urban Green Infrastructure by adopting science-driven Nature-Based Solutions.

Dr Catalano's editorial activity was partially funded by the Institute of Natural Resource Sciences (IUNR) of the Zurich University of Applied Sciences (ZHAW).

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About the Editors

Chiara Catalano, PhD in Technologies for Sustainability and Land Restoration at the University of Palermo (2017) and MSc in Architecture (2008) at the University of Catania. Her eager to travel and to learn different viewpoints took her to live also in London, Zurich, Hannover and České Budějovice where she could alternate professional work, further education, and research activities. From 2017, she got a permanent position as a Researcher at Zurich University of Applied Sciences within the Urban Ecology research group, and currently within the Green Spaces Development. She is engaged in teaching in several BSc modules related to Urban Ecology and Ecosystems Design (in German and English), in supervising both BSc and MSc thesis on these topics, but also in the research and innovation area. Currently, she is leading an international project (DeMo: Design and Modelling of Urban Ecosystems, Switzerland-France), aiming at developing a semi-automatic spatial-based approach to integrate habitats in constructed ecosystems and buildings. Her primary passion as well as the topic of her PhD thesis were near-natural and biodiverse green roof design, construction and monitoring, interests well documented in international peer-review articles and conferences. She landed on the ground of urban green infrastructure inspired by the capability of plants to build dynamic communities able to characterize and reveal specific environmental conditions: plants cannot move, but they give lessons of perfection and slow adaptation, plants cannot speak, but we can observe and study them to plan greener, sustainable and liveable cities.

Maria Beatrice Andreucci, PhD in Environmental Design (Sapienza University of Rome), M.B.A. (INSEAD). She is a registered architect and an economist and focuses her professional activity, research and teaching on the application of environmental technological design and environmental economics theories, principles and methods on urban design, architecture, and landscape architecture projects. Management Committee member of the COST Action "PESFOR-W Payments for Ecosystem Services Forests for Water". Core group member of the COST Action "Circular City: Implementing Nature-based Solutions for creating a resourceful Circular City". Co-chair of the European research project "EKLIPSE - Urban

Biodiversity & Mental Health and Well-being", in cooperation with the French Ministry of the Environment and the World Health Organization. Chair of IFLA "International Federation of Landscape Architects Advisory Circle". Member of SITdA "Italian Society of Technology of Architecture", and EDRA "Environmental Design Research Association". In the last decade, she has authored two books, co-edited four books and published more than eighty papers in peer-reviewed journals and conference proceedings. Her design projects have been published in international journals, and have won recognitions and prizes at international levels. Currently, she works as Research Professor of "Environmental Technological Design", member of the Academic Board of the Ph.D. Program in "Planning, Design, Technology of Architecture"; and expert member of the Scientific Didactic Committee of the II level Master in "Environmental Technological Design", at "Sapienza" University of Rome.

Riccardo Guarino is the victim of an insane passion for plants, which led him to devote his restless youth to the floristic exploration of the southern Alpine and Prealpine Region. From the highest peaks, he slipped downstream and, after years as a castaway in the stormy Sea of Precariousness, he landed at the University of Palermo (Sicily), as a lecturer in Applied and Environmental Botany. His research interests include vegetation ecology, vegetation classification, biogeography, floristics, multifunctional agriculture and conservation biology. About these topics, he authored or co-authored more than 150 peer-reviewed contributions, 8 monographs (including the most recent national flora of Italy, in 4 volumes, digital archives and interactive identification tool), and 11 book chapters. His interest in green infrastructure is driven by the desire to offer plants as much space as possible. Plants have an essential smartness, a simplicity lived with serene grace. Silently passing their time on the earth, they glamorize without clamour, they give without demanding. He who loves plants can see how gross it is to hoard without limits; how illusory it is to claim pre-emption over what, in reality, belongs to everyone; how vain it is to spend time just to satisfy needless needs, believing that this is the right way to escape from a status that looks like "poverty" to our blinded eyes. He who really loves plants realizes that we are getting poorer and poorer while we continue this vast and violent exploitation of our planet.

Francesca Bretzel was born in Milan and now lives in Pisa, where she carried out her superior studies obtaining a degree in Agricultural Sciences with a dissertation on Floriculture. Francesca has achieved a MSc in Landscape and Historic Gardens at Versailles, France. Afterwards, she started her working career at the Institute of Soil Chemistry of the Italian National Research Council in Pisa, now Institute of Research on Terrestrial Ecosystems. Her research interest begun with the dynamics of the soil of urban, degraded and anthropized areas, then widen to the spontaneous and planted vegetation of those areas. Recent projects are focused on the circular economy and the recycle of paper sludges to produce a suitable substrate for plantings and green roofs.

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Salvatore Pasta, PhD in Plant Biosystematics and Ecology (University of Florence, 1994–1997). Since 2018 he works as a researcher at the Unit of Palermo (Sicily, Italy) of the Institute of Biosciences and BioResources (IBBR) – Italian National Research Council (CNR). His main fields of interest are floristics, plant conservation, forest ecology, biological invasions, vegetation dynamics, sustainable agroforestry, island biogeography, landscape history and ethnobotany. Quite recently, he started to pay increasing attention to urban ecology and to the floristic composition, structure and role of urban plant communities. He is the author or co-author of more than 180 peer-reviewed contributions, 5 monographs and more than 50 book chapters concerning the above-mentioned topics. He is vice-chair of the Mediterranean Plants Specialist Group (MPSG) of the International Union for the Conservation of Nature (IUCN) and has been collaborating with several universities in Italy (e.g., Palermo, Catania and Florence) and Switzerland (e.g., Bern, Fribourg and ZHAW in Wädenswil). As a freelance botanist, he has carried out many vegetation and floristic surveys, censuses and assessments and participated in the writing of the management plans of many protected areas and special conservation areas of European community interest and took part in numerous projects focused on plant species conservation in several Mediterranean countries (mostly Sicily, but also Sardinia, Crete and Tunisia) as well as in NW-Germany.

Part III
Nature-Based Solutions and Innovative Design Approaches

Chapter 21
Exploring Regenerative Co-benefits of Biophilic Design for People and the Environment

Maria Beatrice Andreucci, Angela Loder, Beth McGee, Jelena Brajković, and Martin Brown

Abstract There is an increasing awareness of the role that buildings, districts, and neighborhoods play on health in the wake of the Covid-19 pandemic that coincides with pressing climate concerns. This has renewed attention to the benefits of nature for both human and climate health. Buildings, cities, and regions are attempting to align regenerative design principles with human health goals but often lack the tools and knowledge to do so. This is partly rooted in a failure to understand how to apply research and policy for different contexts as well as at different scales. It is also still uncertain exactly what types of nature can lead to which types of benefit, and for whom, despite long-standing research within the environmental psychology, sustainability, and design fields. This chapter outlines key research paradigms that influence the way we understand the benefits of nature, where biophilic design theory sits in this field, and how it can be and has been applied at different scales through two case studies at the building and city scale. This chapter ends with the proposal of new directions for integrating biophilic design into regenerative design and policy.

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C. Catalano et al. (eds.), *Urban Services to Ecosystems*, Future City 17,
https://doi.org/10.1007/978-3-030-75929-2_21

Keywords Biophilia · Health and well-being · Research paradigms · Restorative environmental design · Urban policy · Regenerative design

21.1 Introduction

Integrating nature into our cities, and more recently, our buildings, has long been associated with improved environmental and health outcomes. The recent Covid-19 pandemic has also thrown into sharp relief the role that buildings, districts, and neighbourhoods play in human health: both from location – those living in areas with worse air pollution have been shown to have a higher death rate from Covid-19 (Wu et al. 2020) – and from amenities. For example, the role of urban parks in stress reduction and socialization has renewed attention on the benefits of nature, both in and outside buildings (Surico 2020). However, despite long-standing research on the benefit of access to nature for human and climate health, there is still uncertainty in the sustainability and design fields on exactly what types of nature can lead to which types of benefit, and for whom. Uncertainty is partly rooted in a failure to understand how to understand and apply research on nature and health to different design and policy interventions at different scales. Issues arise also from a disconnection between biophilic design principles and specific health outcomes, as well as from a lack of integration between different fields. This is particularly true as buildings, cities, and regions attempt to align regenerative design goals with human health ones but often lack the tools and knowledge to do so.

This chapter outlines key research paradigms that influence the way we understand the benefits of nature for different sectors, including the workplace, neighbourhood, and city, and explains where biophilic design theory sits in this field. A brief explanation of the key driving beliefs and goals of the most influential research on health and nature, key known outcomes, and how and where they can be used to support the integration of nature into buildings, communities, and cities to support human and ecological health is provided. This is followed by a discussion about how this research aligns, or does not align, with architectural and urban design. Through case studies at the building and city scale, this chapter then examines how biophilic design can be applied and highlights lessons learned, synergies, and trade-offs when implementing nature for both human and ecological health. The contribution ends with key policy and design lessons learned around regenerative design and biophilia, as well as with the indication of new directions for action, particularly with regard to climate change and infectious disease.

21.2 Key Research Paradigms on Benefits from Access to Nature and Health

The last 30 years have provided vast amounts of empirical data to support the now well-established observation that access to nature has benefits for human health and well-being. This has captured the interest of health practitioners who are prescribing time in nature to their patients. It has also been of interest to designers who include access to nature for its diverse benefits, such as in the workplace, and city planners who are interested in the sociocultural benefits of green infrastructure for human health and well-being (Millennium Ecosystem Assessment 2005). Despite this evidence, there remains a disconnect between this vast body of research and the kind of evidence that convinces stakeholders that adding nature will reap real, measurable benefits for their particular project. This is partly due to the types of research – and the paradigms that support them – that lie behind the vast majority of findings that have gotten the attention of policymakers and building owners and that does not always align with the more holistic approach of designers using a *biophilic* framework (Wilson 1984).

There is a wide variety of measures and types of research on health and nature which can complicate comparison and make the establishment of robust results difficult. The most influential research programs in the last 30 years have been based on adaptive or utility paradigms. The adaptive paradigm is grounded in the assumption that biological survival (or evolution) motivates psychological and physiological responses to the environment and that certain environments are better suited to human health and well-being than others. The most common research programs that have come out of the adaptive paradigm have focused either on so-called restorative environments that help to improve cognition or the restoration of attention, notably Stephen and Rachel Kaplan's attention restoration theory (ART) (Kaplan and Kaplan 2005; Kaplan 1995), or on the ability of those restorative environments to support stress recovery and positive mood, notably Roger Ulrich's psychophysiological stress reduction theory (PSR) (Ulrich 1993).

Research testing the ART argues that nature possesses four attributes necessary to hold our attention involuntarily and be experienced as restorative: fascination, mystery, coherence, and the feeling of *being away* (Hartig et al. 1991). A large subset of this research has looked at aesthetic preferences for different types of nature, arguing that some types of nature are more conducive to restoration than others and that nature is more restorative than urban environments (Kaplan and Kaplan 2005). Research testing the PSR theory also uses an evolutionary biology theory, which states that, because we evolved in *nature*, we need to feel connected with natural stimuli; this attitude is called *biophilia* (translated as a love of nature) (Ulrich 1993).

The utility paradigm, though related, focuses on the role that nature plays as a quality of an environment to satisfy current personal or interpersonal needs, often measured by levels of physical activity, restorative experiences, or social cohesion, interaction, and safety.

Though there is qualitative research that has been done in the adaptive and utility paradigms, the vast majority of this research follows a psychometric research approach, which aims to generalize human relationships with nature through quantifiable measures (Zufferey and King 2016). Research also tends to follow, or support, a linear, individualistic, and reductionist approach to understanding how and why nature supports health, focusing on the mechanism between the phenomena (here nature) and the response in the individual (Herzog et al. 2002; Patterson and Williams 2005). This approach that aligns well with green building paradigm has created a vast amount of data on the benefits of access to nature (outlined below), has been very influential in public policy, and has provided much of the support for adding nature into buildings, neighbourhoods, and cities to date. However, this type of linear and somewhat mechanistic approach to nature and health does not always align well with the more holistic, design-thinking approach seen in biophilic design and green infrastructure work to support human health, as will be explained further. This approach also tends to miss some of the collective lived experience of place aimed at in biophilic design.

Critics have argued that studies following the adaptive paradigm tend not to address the larger context of place including economic, social, and political forces that structure environmental conditions and distributions of power that influence access and regulate these conditions within society. For example, some people may be threatened by *messy* ecological urban greening projects despite their good intentions and environmental value. Similarly, the utilitarian paradigm has been criticized for its limited understanding of the socio-economic and sociocultural factors influencing access to nature, the reduction of environmental values to utility, and the general disregard for the symbolic meaning of nature for humans. This can be problematic when designing biophilic interventions for specific populations or disadvantaged communities, when aiming to create a positive sense of place, or even when trying to compare biophilic interventions with complex outcomes such as workplace productivity. Thus, while the adaptive and utility research has provided strong evidence to support the health goals of biophilic design, biophilia's focus on sense of place, lived experience, and holistic design-thinking may be more aligned with some of the relational and sense of place work on the human relationship to nature that rarely gets cited. Why is this important? By understanding the strengths and limitations of research being used to support nature interventions for health at different scales, designers, engineers, and building owners can be better equipped to draw upon the right research for the right context. This in turn can build trust and better align design goals with the specific context and outcomes desired. Below are some examples of what kind of research can be applied to which context, followed by its application in case studies.

21.2.1 Physiological and Mental Health and Well-Being

As indicated above, the adaptive and utility paradigms have created a vast amount of research linking access to nature and improved physiological and mental health and well-being. Some researchers have theorized these relationships as a series of pathways: (1) stress reduction, (2) physical activity, (3) social cohesion, and (4) air quality (Hartig et al. 2014).

The first pathway – following the adaptive paradigm – has traditionally received the most empirical and theoretical attention and focuses on the restoration theories outlined above: (a) the evolutionary-based positive affective responses to nature (Stress Reduction Theory: Ulrich et al. 1991) and (b) the cognitive recovery and resource replenishment after viewing natural settings (Attention Restoration Theory: Kaplan 1995). These two theories mainly rely on aesthetic and visual qualities of the natural environments and are related to presumed intrinsic characteristics of nature-based on evolutionary theory and the related biophilia (or *biophobia* – fear of nature) (Kellert and Wilson 1993; Ulrich 1993). Studies following this paradigm have been done at multiple scales and with various types of nature – ranging from lab studies to wilderness excursions. This variety speaks to the strength of the research, though their application at a building scale has been harder to evaluate, given the high number of factors involved. Importantly, the underlying evolutionary paradigm – i.e., that love of nature is innate – can seemingly hide cultural, socio-economic, and power differences that influence the success of different urban greening interventions and equitable access to nature for all.

The second pathway, physical activity, follows the utility paradigm and is recently gaining attention. Outdoor physical activity (as opposed to sedentary behaviour) has demonstrated positive effects on mental health. Experimental studies have pointed at added benefits of physical activity in green areas as opposed to indoor or artificial urban areas (Barton et al. 2012). However, cross-sectional and/or epidemiological studies at the neighbourhood scale show unclear results (van den Berg et al. 2019). This is partly due to the difficulty of applying lab-based studies to real-world situations, where other explanatory variables may be influencing outcomes, and the need to take into account other factors such as green space characteristics, location, and other influences on behaviour or preferences. For example, factors other than green space availability may facilitate or hinder physical activity. A study in Denmark found that it was not necessarily the amount of green space in the proximity of participants' homes to be appreciated but the availability of specific green space characteristics such as walking routes, wooded areas, a water area, or a pleasant view (Schipperijn et al. 2013).

Improvement in social interactions (at the individual level) and social cohesion (at the neighbourhood level) is a third proposed pathway linking nature exposure with mental health. Research in this pathway often varies in its research paradigm or approach. For example, the design of urban parks have been found to influence the relationship between green space and social cohesion (Peters et al. 2010). Research like this often falls under a utility paradigm, i.e., what characteristics of nature influence desired uses or behaviours. Conversely, the link between social interaction and mental health has been firmly established (Holt-Lunstad et al. 2010) although the link between social interactions and social cohesion and green space has received less research attention than the first two pathways. This type of research sometimes follows a public health socioecological approach (which looks at complex factors influencing health outcomes) that enables it to be adopted by public policy (Jennings et al. 2016).

Air pollutants, the fourth pathway, have also received less attention. Air pollution does have pronounced negative effects not only on physical health and mortality (Sun and Zhu 2019) but also on mental health (Klompmaker et al. 2019) and cognitive performance (Calderón-Garcidueñas et al. 2014). Besides a direct link between air pollution and mental health, it has also been proposed that air pollution, together with traffic-related sounds, can put a constraint on the restorative potential of an environment (von Lindern et al. 2016). Trees and plants do not reduce all pollutants; some, for instance, also release pollen which may aggravate allergies (Cariñanos et al. 2019; Hartig et al. 2014), thus taking into account ecosystem disservice is equally important. This last pathway can be one of the most easily integrated into regional-level planning and regenerative policies and can be a good way to balance synergies and trade-offs at this scale (Fig. 21.1). However, the benefits of nature

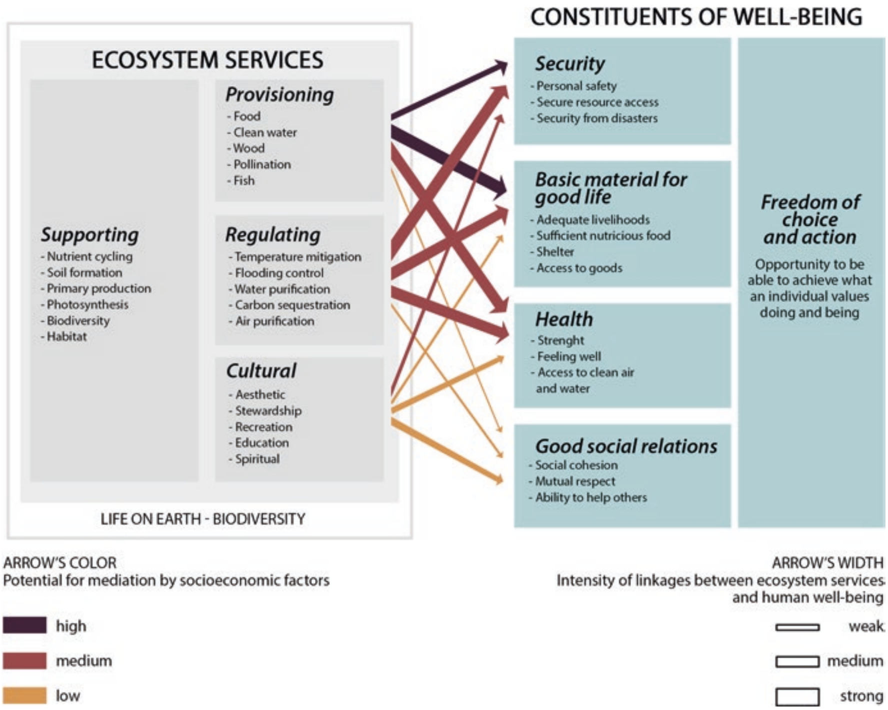

Fig. 21.1 Services and constituents of wellbeing. (Adapted from Millennium Ecosystem Assessment 2005)

explored in typical city or regional-level analyses and policies often lack the specific detail on health outcomes seen in the other three pathways, leaving building-level owners feeling a sense of disconnection between project-level nature-health outcomes and regional goals.

21.2.2 Cognitive Function and Performance

To assess cognitive function and performance, research about the benefits of nature in the workplace can be critically examined in order to guide design interventions. For example, multiple studies have shown improved task performance from access to nature – measured often through cognitive tests and proxies for productivity. These studies have been criticized for not replicating the actual day-to-day tasks of office workers, and there have been very few studies done in situ for office workers.

The benefits of improved task performance from better concentration are supported by multiple studies in nature (Choudry et al. 2015; Li et al. 2018). These proxies should not be used alone to prove increased performance; however, if combined with other measures at an individual and organizational level, they can provide a reasonable indication of cognitive function and performance in the workplace. This means that biophilic designers can confidently argue that access to nature can support better concentration and performance for those nearby (Loder 2020).

21.2.3 Biophilic Design Attributes and Troubles of Implementation

E.O. Wilson (1984) originally proposed the *biophilia hypothesis* which prompted the modern biophilic design movement. He defined *biophilia* as the "innately emotional affiliation of human beings to other living organisms. Innate means hereditary and hence part of ultimate human nature" (Wilson 1984: 31).

Wilson proposed that people have an innate need to connect with nature and natural processes. S.R. Kellert and E.O. Wilson then applied this concept to the built environment (1993). The idea went beyond just working with a green and plant-like environment. It was initially operationalized in Kellert's proposed attributes for *biophilic design* (2008), where he introduced key dimensions, elements, and attributes of biophilic design. As two main dimensions, the author identified organic/naturalistic and place-based/vernacular. Organic dimension refers to "shapes and forms in the built environment that directly, indirectly, or symbolically reflect the inherent human affinity for nature" (Kellert 2008: 5). Vernacular dimension refers to "buildings and landscapes that connect to the culture and ecology of a locality or geographic area" (Kellert 2008: 6).

As Kellert points out, this latter dimension includes a sense or a spirit of place. Further classification goes to 6 main elements, which then break out into more than 70 biophilic design attributes. These attributes are as simple and straight forward as presence of water, air, sunlight, plants, and animals, but also, there are more complex ones – sensory variability, information richness, exploration and discovery, or geographic, historic, ecological, and cultural connection to place. Importantly, biophilic designers need to understand that the environment can be an atmosphere, a process, or an experience. If architecture is not atmospheric and does not generate a *sense of place*, then it is *lifeless.* Recognition of atmospheres, ambiances, energies, mediation, experiences are considerations of biophilic design and are important if we want biophilic design to be meaningful and a feel-good lived experience.

> The ambiance or atmosphere of a room or an urban space is the overall feeling and tuning of the experience. It is a non-material or peripheral experience that tunes our minds in a specific way. We feel atmospheres immediately and without being conscious of the process. The final target of the design is not the physical building but its impact as a lived experience. (Pallasmaa 2018: 2, 3)

Within Kellert's theory, defined elements and attributes are open to revision, while others are improvable over time. There have been some further revisions to Kellert's work, an example of which is Terrapin Bright Green's *14 Patterns of Biophilic Design – Improving Health and Well-Being in the Built Environment*. This report defines 14 patterns of biophilic design organized into Nature in the Space, Natural Analogues, and Nature of the Space Patterns. Another is the Biophilic Interior Design Matrix which adopts and adapts Kellert's work to operationalize it for interior environments (McGee et al. 2019) in order to provide tangible and clearer guidance for designers.

Kellert (2008) also pointed out some of the difficulties with biophilic design that designers experience in practice, especially when translating conceptual and abstract attributes into design. Biophilic design is not always straightforward in its guidelines, and many people want clear rules that they can apply to design or that can be added into modelling software. The patterns and attributes of biophilic design are almost philosophical and require a holistic approach and profound understanding of both human and non-human environmental factors and components – their purpose and relationship that generates the overall atmosphere. Examples include their sense of place and the *lived experience*, which is the ultimate goal of architecture. Good biophilic designers must have highly developed both rational and irrational skills in designing space. They must understand all dimensions of space and human experience – mental, sensory, temporal, natural, cultural, traditional, etc., as well as a sense of playfulness. This kind of approach to the benefits of nature does not always align well with health-nature scientific evidence that uses a psychometric research paradigm, which can lead to a disconnection, which in turn can be expressed as a lack of knowledge about existing health-nature research and/or as a difficulty translating biophilic attributes into design goals that can be measured and quantified.

21.3 Applying Research to Practice

Biophilic design is illustrated below at two different levels of implementation: buildings and city scale. This emphasizes the value of biophilic design principles for people and the interior environment, followed by its application at a regional scale for regenerative design and resilience.

21.3.1 The Biophilic Interior Design Matrix

How can we apply biophilia at a building scale and codify the principles for designers? Since people spend most of the day inside, it is necessary to further address how to support biophilic design and its related benefits at the building scale. The Biophilic Interior Design Matrix was recently developed attempting to operationalize biophilic design to give guidance for interior environments without being prescriptive (McGee et al. 2019). This includes looking at a variety of experiential considerations like sensory comfort, psychological feeling, and spiritual experience. It was tested with interior design practitioners using evidence-based design, to develop the language to be user-friendly and offer specific examples for clarity. The Matrix has six elements offering connections to nature originally based on Kellert's (2008) work. The categories are as follows: (1) actual natural features (what we usually think of when we talk about biophilia, bringing actual nature inside), (2) natural shapes and forms (representations of nature), (3) natural patterns and processes (natural features that change over time like weathered leather), (4) colour and light (design considerations like pools of light), (5) place-based relationships (historical connections like old portraits), and (6) and human-nature relationships (things that when paired represent nature-like order and complexity, when used together there is harmony). These 6 elements include 54 interior design attributes that provide a great variety of design features.

The Matrix can be used as a post-occupancy assessment tool, and it also has been useful during the design process as a conceptual aid and creativity boost. The Matrix also helps designers feel more confident and knowledgeable about biophilic design after using it. Aiming at overcoming the elusiveness of the biophilia concept, a growing body of research is more recently linking specific biophilic attributes with evidence-based design. When one seizes to deeply understand the core concepts of biophilia, respect its values, and constantly rediscover them, one practises biophilic design with ease and playfulness. The Matrix supports this and aids users to better understand the concepts of biophilic design, specifically biophilic interior design (see Fig. 21.2 for full attribute list).

Fig. 21.2 Biophilic Interior Design Matrix. (Source: Beth McGee et al. 2019)

21.3.2 *Case Study: The University of Florida Clinical and Translational Research Building*

With the growing research and interest focused on biophilic design, it is interesting to look at a building specifically designed and constructed as a model to highlight the biophilic indoor attributes. The University of Florida Clinical and Translational Research Building was built in 2013 by a well-known architecture firm, and it was inspired by biophilia (University of Florida Clinical and Translational Research Building 2014). The concept "emerged from the desire to provide sustainable healing, working and educational environments" (University of Florida Clinical and Translational Research Building 2014: online). The approach the firm took to site the building aligns with biophilia in understanding the existing environment and surrounding context, including both the geography and man-made structures. It also integrates sustainable design features like solar panels and recycled building materials. The LEED Platinum certification represents the University's sustainability mission and commitment which is "protecting the environment, health, and well-being of our employees, customers and the global communities where we operate", according to the plaque in the lobby. This further connects to the long term of goal of biophilia to be restorative in all manners (Derr and Kellert 2013).

This facility is 120,000-square-feet with two joined wings at a central atrium. This layout is an example of the attribute *linked series and chains*. Looking only at the atrium, there is a prominent staircase that encourages moving and fitness that also represents the attribute *exploration/discovery*. The west-facing two-storey curtain wall provides ample *natural light* and *spaciousness*. It has a view to the outside wetland (*views and vistas*) and Cairn, a sculpture by Adam Frezza and Terri Chiao. There is also a nice play of light from the artificial linear recessed downlights and the sunlight reflecting off the flooring (*reflected light*). The two-tone flooring continues to the outside and creates a nice continuity that represents *inside-outside*. These are a few of the attributes included (Fig. 21.3).

This space has a variety of biophilic attributes that are supported by a thoughtful application of features. During testing of the recent Matrix revision, this space did receive comments from experienced design practitioners that the space seemed very cold and not optimally biophilic. It appears that although a design may do a great job in adding direct visual connection with nature and a few strong nature-based features, this may not fulfil all the experiential components required for biophilia. Using a higher variety of design attributes may be more successful in eliciting connections to nature, which aligns with the idea that our innate need to connect with nature would require variety similar to natural environments that are rich with sensory feedback. Looking at the six main elements and seeing how one can use features from each element to further deliver more variety can be a stronger biophilic strategy for designers in eliciting preference as greater variety appears to support increased preference for a space. The wider variety of items used in the interior, when also thoughtfully applied, theoretically make the interior feel more like a nature-based environment. This seems to fit the biophilia hypothesis. Given the fluid

Element	Site Image	Attributes
Actual Natural Features		Views and Vistas* Habitats*
Natural Shapes & Forms		Botanical Motifs* Animal* Shells & spirals* Fluid forms Abstraction of nature Inside-Outside*
Natural Patterns & Processes		Sensory richness Age, change & the patina of time Area of emphasis Patterned wholes Bounded spaces Linked series & chains Integration of parts to wholes Complementary contrasts Dynamic balance & tension Natural ratios & scales
Color and Light		Composition Communication Preference Pragmatics Natural light* Filtered light Reflected light* Light as shape & form Spaciousness* Spatial variety Space as shape & form Spatial harmony
Place Based Relationships		Geographic connection to place Ecological connection to place Cultural connection to place Integration of culture and ecology
Human Nature Relationships		Order AND complexity Curiosity AND enticement Attraction AND attachment

Fig. 21.3 Elements and attributes of biophilic interior design included in lobby, based on the Biophilic Interior Design Matrix. Starred items are strongly present. (Images shown help illustrate the overall context. Photos by Beth McGee et al. 2019)

nature of biophilic design, this codification can help link the more abstract elements of biophilia with design guidelines. Combined with data on the benefits of access to nature outlined above, this example provides a hybrid approach to translate research to practise effectively.

21.3.3 Oslo, Norway. The Blue-Green City: A Conscious Choice

Looking next to the city scale, the translation of biophilic design interventions for human health and well-being is found in the City of Oslo. The City of Oslo, in Norway, spans 454 km^2 and consists of 32% built-up areas, 60% forests, 2% agricultural land, and 6% freshwater. The city is situated at the end of the Oslo Fjord and is surrounded by water and islands to the south and forests to the north and east. Ten main rivers run through the urban areas (Oslo Kommune 2019).

Since the end of the nineteenth century, the City of Oslo has invested in its blue-green infrastructure, acquiring several forests and islands surrounding the city in order to provide its citizens with recreational areas and to secure potable water. As a result, large tracts of forests surround two-thirds of the urban areas, and drinking water is sourced from lakes within the city's borders.

Ninety-four per cent of the Oslo inhabitants live within 300 m of a blue-green area. Biophilic planning and design principles (Box 21.1) – following Oslo official plans – led to the construction of parks and gardens, as well as of 220 km of greenways and footpaths that contribute to easy access to nature, and sustainable transportation in the city while providing ecological corridors for plants and animals.

Box 21.1: Attributes of Biophilic Design

Direct experience of nature

- Light
- Water
- Vegetation
- Animals
- Weather conditions
- Natural landscape and ecosystems
- Fire

Indirect experience of nature

- Images of nature
- Natural Materials
- Natural Colours
- Simulated natural light and air
- Naturalistic shapes and forms
- Evoking nature
- Information richness
- Age, change, and patina of time
- Natural geometries
- Biomimicry

Experience of space and place
Prospect and refuge
Organized complexity
Integration of parts to wholes
Transitional spaces
Mobility and wayfinding
Cultural and ecological attachment to place

(Adapted from Kellert and Calabrese 2015)

The *iceberg*, i.e., the Oslo Opera House, conveys concepts of togetherness, joint ownership, and easy and open access for all. The Harbour Promenade, opened in 2015, is one of Oslo's newest paths and stretches for 9 km along the waterfront. Parks adjacent to waterways play a central role in Oslo's action plan for stormwater management by functioning as retention basins during extreme weather events. In order to accommodate its growing population, sites along the waterfront, in the city's Fjord City project – areas like Tjuvholmen, Aker Brygge, Barcode, and Sørenga – have been more recently transformed from shipyards and dry docks into compact densely populated eco-neighbourhoods that combine 9000 new dwellings, 45,000 new workplaces next to shops and restaurants, and more than 50 ha of parks and *biophilic* public spaces. The bathing water quality is now either good or excellent, and two outdoor public sea baths were opened in 2013 and 2015 (Oslo Kommune 2019) (Fig. 21.4a. b).

Worldwide, edible city projects have demonstrated that cultivated urban spaces (e.g., allotment gardens, edible forest gardens, edible urban forests) can improve social cohesion, healthy ageing, and well-being (Andreucci et al. 2019). Oslo's horticultural therapy project of Losæter *Garden of Senses* evolved from grassroots movements and stands out as a biophilic success. Located in Sørenga near the Oslo Fjord the project has emerged through an organic process that was started by the artist group Futurefarmers in 2011. The project belongs to the *Sprouting Oslo* programme, an outstanding example of the 2019 Green Capital's commitment to productive, inclusive, and *healing* urban landscapes (Andreucci et al. 2019) (Fig. 21.4a, b).

As the European Green Capital 2019, Oslo has taken on an important task, i.e., to be a role model to other cities. Oslo is small enough to test innovative biophilic solutions. However, Oslo is also big enough for those solutions to be scaled up to larger cities.

Oslo's population is expected to increase 35% by 2040. Population growth demands densification near transport nodes and regeneration of underused areas. In these areas, Oslo is therefore currently implementing biophilic planning guidelines in order to encourage the establishment of new green areas and meet the demand from all residents.

		Environmental Features	Natural Shapes and Forms	Natural Patterns and Processes
SCALE **Building** PLACE **Opera House**		Color, Water, Air Sunlight Natural Materials Views, Vistas Landscape Habitats, Ecosystems	Simulation of Natural Features Biomorphy, Geomorphology, Biomimicry	Sensory Variability Information Richness Central Focal Point Bounded Spaces and Transitional Spaces Dynamic Balance and Tensions
SCALE **Urban Park** PLACE **Bee Sanctuary**		Color, Water, Air Sunlight Plants, Animals Natural Materials Landscape Habitats, Ecosystems	Botanical and Animal Motifs Simulation of Natural Features	Sensory Variability Information Richness Patterned Wholes Linked Series and Chains
SCALE **District** PLACE **Akerselva**		Color, Water, Air Sunlight Plants, Animals Natural Materials Views, Vistas Greewalls Geology, Landscape Habitats, Ecosystems	Botanical and Animal Motifs Simulation of Natural Features Trees and Columnar Support Biomorphy, Geomorphology, Biomimicry	Sensory Variability Information Richness Age, Change and Patina of Time Bounded Spaces and Transitional Spaces Integration of Parts to Wholes
SCALE **Neighborhood** PLACE **Sørenga**		Color, Water, Air Sunlight Plants, Animals Natural Materials Views, Vistas Geology, Landscape Habitats, Ecosystems	Botanical and Animal Motifs Simulation of Natural Features Biomorphy, Geomorphology, Biomimicry	Sensory Variability Information Richness Age, Change and Patina of Time Bounded Spaces and Transitional Spaces Integration of Parts to Wholes Dynamic Balance and Tensions
SCALE **Community** PLACE **Losæter**		Color, Water, Air Sunlight Plants, Animals Natural Materials Views, Vistas Green Walls Geology, Landscape Habitats, Ecosystems	Botanical and Animal Motifs Trees and Columnar Support Shapes Resisting Straight Lines and Right Angles	Sensory Variability Information Richness Age, Change and Patina of Time Growth and Efflorence Patterned Wholes Bounded Spaces and Transitional Spaces

Fig. 21.4 (**a**, **b**) Elements and attributes of biophilic design in Oslo. (Adapted from Kellert 2008. Photos by Maria Beatrice Andreucci)

21.4 Biophilia and Connection to Nature: A Missing Link for Sustainable Behaviour and Climate Change?

Climate change has been described as:

> […] the most serious threat to global economic, social and environmental stability in recorded history […] with many […] prevalent human diseases linked to climate fluctuations. (Africa et al. 2019: 2)

Some have argued that it is our destruction of natural habitats that helped the current Covid-19 pandemic and that we can expect more zoonotic-originated diseases in the future:

> There is a single species that is responsible for the Covid-19 pandemic - us. As with the climate and biodiversity crises, recent pandemics are a direct consequence of human activity. (Settele et al. 2020: 1)

Light and Space	Place Based Relationships	Evolved Human Nature Relationships		
Natural Light and Shadow Filtered and Diffused Light, Reflected Light Spaciousness, Space as Shape and Form Spirit of Place and Avoid Placelessness	Historic, Geographical, Cultural, Ecological Connection to Place Landscape Features that Define Built Form Spirit of Place and Avoid Placelessness	Order and Complexity Curiosity and Enticement Attraction and Beauty		SCALE Building PLACE Opera House
Natural Light and Shadow Filtered and Diffused Light, Reflected Light Spatial Variability and Harmony	Historic, Geographical, Cultural, Ecological Connection to Place Indigenous Materials Landscape Orientation and Ecology	Information and Cognition Curiosity and Enticement Exploration and Discovery Affection and Attachment		SCALE Urban Park PLACE Bee Sanctuary
Natural Light and Shadow Filtered and Diffused Light, Reflected Light Spaciousness, Space as Shape and Form Spatial Variability and Harmony	Historic, Geographical, Cultural, Ecological Connection to Place Landscape Orientation and Ecology Spririt of Place and Avoid Placelessness	Exploration and Discovery Affection and Attachment Security and Protection Attraction and Beauty		SCALE District PLACE Akerselva
Natural Light and Shadow Filtered and Diffused Light, Reflected Light Spatiousness, Space as Shape and Form Spatial Variability and Harmony	Historic, Geographical, Cultural, Ecological Connection to Place Indigenous Materials Landscape Features that Define Built Form	Curiosity and Enticement Exploration and Discovery Security and Protection Attraction and Beauty		SCALE Neighborhood PLACE Sørenga
Natural Light and Shadow Spatiousness, Space as Shape and Form Spatial Variability and Harmony Inside-Outside Spaces	Indigenous Materials Landscape Orientation and Ecology Landscape Features that Define built Form Spirit of Place and Avoid Placelessness	Prospect and Refuge Security and Protection Curiosity and Enticement Attraction and Beauty Affection and Attachment		SCALE Community PLACE Losæter

Fig. 21.4 (continued)

In figuring out how to address future global emergencies like Covid-19, our connectedness and relationship with nature, and in particular biophilic design, may be key for improving sustainable behaviour and our well-being. Rather than relying on abstract universal ideas of *nature* to encourage sustainable behaviour, using design and policy at a building, neighbourhood, and city scale to connect our daily lives with nature may encourage connection and make action feel more meaningful. Improving sustainable behaviour might then help address the current climate and disease crisis. For example, while inaction and business as usual has plagued climate change policies, Covid-19 has exposed the connection between climate change and infectious disease, with those who have been exposed to air pollution dying at a higher rate (Wu et al. 2020).

Covid-19 has also highlighted the role of nature in mental health and socialization. We have been forced to slow down and pay attention to nearby nature and the role it can play in our mental and physical health. Urban parks, or the lack thereof, are making headlines for their role in nurturing quarantined people's mental and physical health (Surico 2020). Throughout the lockdown, government, regional, and city officials have recognized the importance of space, from country parks to city parks and urban green spaces, as vital for physical and mental well-being. Getting out of buildings, into natural green space, walking, or *forest bathing* has long been recognized as beneficial and a prescribed option for general practitioners. Even observing the ordered complexity of fractals, which are self-similar scales found within nature, can reduce stress. This is a key relief needed during Covid-19.

The (re)discovery of the joy and refuge of nature, specifically local nature on doorsteps and in our gardens, has led to newfound delight in fractal minutiae around us and a slowing down of the pace of urban life. This slowed pace may be key to increasing the restorative benefits of nature. Isolation and quarantine have slowed down lives, providing the time to notice, in real time, the unfolding of nature as seasonal changes emerge. This noticing of the *otherness* of nature and the seasons has been linked to higher concentration and restoration of attention for office workers in downtown central business districts. Consequently, the incorporation of time may be key for successful biophilic design, which can highlight the changing patterns that a building's non-human aspects create. This may prove to also be key for resilience in current uncertain times.

The connectivity with nature from slowing down from Covid-19 has also been balanced with the heightened awareness of social injustice and those who lack access to space, nature, and safety. Access to high-quality urban green space is beginning to be recognized as a public good by many cities, and the unequal access to it has spurred recent urban greening initiatives and been an integral part of updated resiliency plans (Loder 2020). Incorporating some of the work done by cities and research from relational and political ecology work can help to bridge this traditional blindness in biophilia. To be socially just, ensuring the right to nature access, to fresh air and water, and to natural light in living spaces must be equally available to all:

> Biophilic design is justifiably critiqued for its inequity: the health, happiness and productivity of humans is privileged over that of other species, and (*de facto*) the approach is most accessible among clients of means. (Africa et al. 2019: 2)

Addressing this barrier and imagining a more inclusive biophilic design need to be more prominently addressed at all scales, from single rooms, to cities, and to the entire planet.

21.4.1 Linking Biophilia to Larger Ecological Systems: Rewilding and Ecosystem Design

Successful ecological and urban landscapes can join up existing urban green spaces for greater access and can create pollinator pathways, which further supports life on the planet. For example, parks and roadside verges in London's National Park City initiative can help achieve their regional goal to green and rewild the city for people and nature. This initiative is "an acknowledgement to how vitally urban lives are bound up with and enriched by nature" (Macfarlane 2020). Such greening and rewilding pathways are being extended across living walls, roofs, courtyards, and gardens of the urban built environment (e.g. British Land 2020). As building designs blur outside/inside envelops, pollinator pathways can now continue right up to the biophilic desk plant, rewilding the building and enabling living biophilia.

Biophilia – and in particular the encouragement of a deeper connection to nature – has the potential to shift nature-based design and policy from the nice-to-have towards a holistic, ecosystem-friendly approach, enabling deeper regenerative meaning and uptake by buildings, cities, and regions. This has been happening in some design community circles which are viewing the non-human (nature, place), human (culture), and built environment habitats through a different biophilic lens. Practical examples at a project level include biophilic design workshops that have incorporated mindfulness approaches and encouraged the exploration of the relationship with place. This places the design team in a state of mind that asks the land for permission to build and seeks reciprocity with soils, native plants, and biodiversity.

This kind of evidenced-based biophilic research and practice embraces *salutogenic* thinking, the medical concept (Antonovsky 1987) that encourages a focus on factors that *improve* and *support* human health and well-being rather than on factors that reduce illness (Brown 2016). With the health and well-being of humans intrinsically linked to the health and well-being of the planetary ecosystems, the combination of biophilic and *salutogenic* design approaches may provide a more holistic framework to link ecosystem, human, and non-human dimensions. Considering that, at a building scale, research attention has tended to focus on threats to health, and a more holistic way of thinking would also be useful to foster health-promoting environments (Loder 2019).

On a larger scale, an emerging trend is the Bio-Leadership, i.e. a concept of an ecosystem made of people and projects transforming leadership by working with nature (Roberts 2020). Within the design and policy world, the concept switches from a mechanistic perspective (where the world is seen to function as a machine) to a natural fluid approach. This framework has been used to describe the hoped for next era of our relationship with the environment. This new way of envisioning the nature-human relationship in design and policy aims to nurture a *co-evolving mutuality* (Mang et al. 2016) and may provide hope for both a more equitable and regenerative future. If combined with work on equitable access to nature, along with evidence on the benefits of access to nature at multiple scales, this large-scale application of biophilic principles can play a part to restore both human and ecological health.

21.5 Concluding Remarks

Human disconnection with nature has already negatively impacted mental and physical health. Buildings today are often designed, constructed, and operated *apart from* nature, rather than as *a part of* nature. Over the last 30 years (since World Commission on Environment and Development 1987), sustainable design and construction has been a core element in the built environment, and yet climate and biodiversity indicators have worsened, while the impact of building design and practice on health outcomes is increasingly researched but still remains opaque. Evidence from the last 30 years has shown that contact with nature in general can improve human health, but there are gaps in the application at different scales and a lack of understanding of which research to apply to which situation.

Conversely, biophilic design is growing in popularity, but it still suffers from a lack of specificity on research outcomes and variables. There is a tendency for it is to be dismissed from many design circles as *nice to have but dispensable* versus an effective intervention to improve health and performance. The research on nature and health to date supports many of the biophilic design attributes outlined above; however, in practice biophilic design is often limited to a few variables, which limits its application in design practice. Furthermore, there is still much that is not known about the potential benefits of biophilic design interventions individually and as a whole. This gap has not been overcome by the confusion of *green* design interventions in green buildings over the last few decades, which may or may not have had any link to evidence-based or biophilic design. It is also complicated by the differing underlying paradigms in nature and health research and design: research that examines nature as a linear input with an expected outcome does not align well with the more philosophical sense of place and lived experience goals of biophilic design.

Lastly, effective integration of evidence-based research and design on nature and health requires an acknowledgement and understanding of how it can be applied at different scales. This is particularly true when attempting to align building-level, neighbourhood-level, or city-level initiatives with regional resiliency or climate change initiatives. There is still a need to provide a synthesis with respect to the available knowledge about the relationship between nature design and policy interventions, natural systems, and health. This seems to be confirmed by the growing demand from policymakers. For instance, in the *Urban Green Spaces: Brief for Action* published recently, the World Health Organization (WHO 2017) emphasized the need for a change in urban health initiatives with a strong focus on the creation, promotion, and maintenance of green spaces, with an explicit call for expert advice (WHO 2017). How this expertise is developed is a current gap in both education and practice.

The discussion above argues that understanding the strengths and limitations of the most influential research on health and nature can help it support and align with biophilic design. This knowledge can result in a more effective and holistic understanding of how nature can be incorporated into our buildings, neighbourhoods, and cities. Critically combining research on health and nature with biophilic design principles may also provide a more holistic and just approach to connecting us with nature and encouraging sustainable behaviour. This can further support regenerative policies and action. As we look to life with and after Covid-19, the shape of the future built environment remains unknown, but it provides an opportunity for re-evaluation and new insights about our human, natural, and built environment relationships.

Acknowledgements This book chapter is based on research carried out as part of the COST Action CA16114 RESTORE "REthinking Sustainability TOwards a Regenerative Economy", supported by COST (European Cooperation in Science and Technology).

Author Contributions Conceptualization: Maria Beatrice Andreucci and Angela Loder; literature review: all authors; writing – original draft preparation: all authors; writing – review and editing: Maria Beatrice Andreucci and Angela Loder; visualization: Maria Beatrice Andreucci and Beth McGee; funding acquisition: Maria Beatrice Andreucci, Jelena Brajcović, and Martin Brown

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Index

C. Catalano et al. (eds.), *Urban Services to Ecosystems*, Future City 17,
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