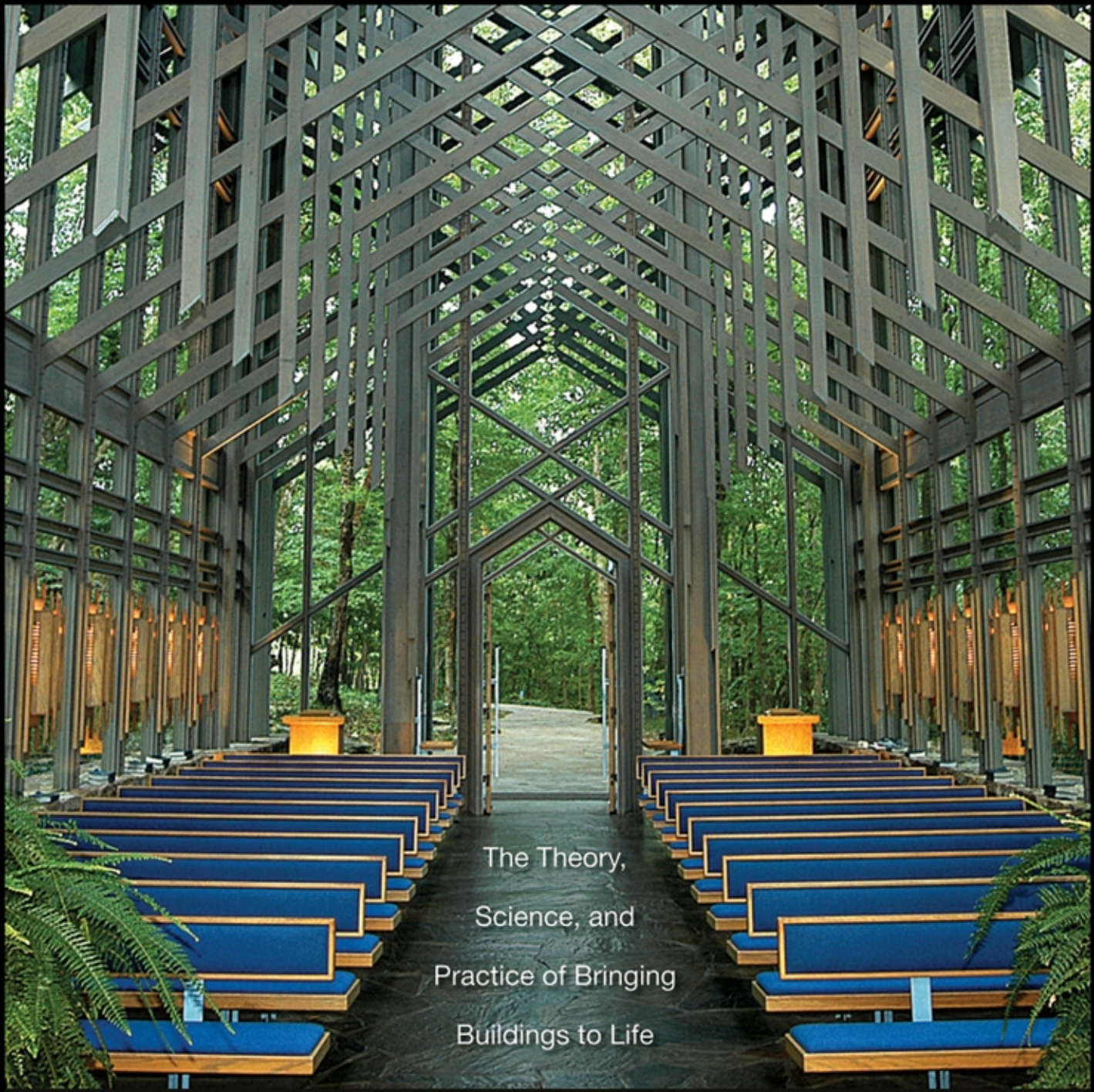

Biophilic Design

Stephen R. Kellert • Judith H. Heerwagen • Martin L. Mador

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The Theory, Science, and Practice of Bringing Buildings to Life

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Preface

Stephen R. Kellert and Judith H. Heerwagen

This book immodestly aspires to help mend the prevailing breach existing in our society between the modern built environment and the human need for contact with the natural world. In this regard, the chapters in this volume focus on the theory, science, and practice of what we call *biophilic design*, an innovative approach that emphasizes the necessity of maintaining, enhancing, and restoring the beneficial experience of nature in the built environment. Although we present biophilic design as an innovation today, ironically, it was the way buildings were designed for much of human history. Integration with the natural environment; use of local materials, themes and patterns of nature in building artifacts; connection to culture and heritage; and more were all tools and methods used by builders, artisans, and designers to create structures still among the most functional, beautiful, and enduring in the world.

The authors in this book represent widely diverse disciplines, including architects, natural scientists, social scientists, health professionals, developers, practitioners, and others who offer an original and timely vision of how we can achieve not just a sustainable but also a more satisfying and fulfilling modern society in harmony with nature. Collectively, they articulate a paradigm shift in how we design and build with nature in mind. Still, biophilic design is not about greening our buildings or simply increasing their aesthetic appeal through inserting trees and shrubs. Much more, it is about humanity's place in nature, and the natural world's place in human society, a space where mutuality, respect, and enriching relation can and should exist at all levels and emerge as the norm rather than the exception.

Biophilic design at any scale from buildings to cities begins with a simple question: How does the built environment affect the natural environment, and how will nature affect human experience and aspiration? Most of all, how can we achieve sustained and reciprocal benefits between the two?

The idea of biophilic design arises from the increasing recognition that the human mind and body evolved in a sensorially rich world, one that continues to be critical to people's health, productivity, emotional, intellectual, and even spiritual well-being. The emergence during the modern age of large-scale agriculture, industry, artificial fabrication, engineering, electronics, and the city represents but a tiny fraction of our species' evolutionary history. Humanity evolved in adaptive response to natural conditions and stimuli, such as sunlight, weather, water, plants, animals, landscapes, and habitats, which continue to be essential contexts for human maturation, functional development, and ultimately survival.

Unfortunately, modern technical and engineering accomplishments have fostered the belief that humans can transcend their natural and genetic heritage. This presumption has encouraged a view of humanity as having escaped the dictates of natural systems, with human progress and civilization measured by its capacity for fundamentally altering and transforming the natural world. This dangerous illusion has given rise to an architectural practice that encourages overexploitation, environmental degradation, and separation of people from natural systems and processes. The dominant paradigm of design and development of the modern built environment has become one of unsustainable energy and resource consumption, extensive air and water pollution, widespread atmospheric and climate alteration, excessive waste generation, unhealthy indoor environmental conditions, increasing alienation from nature, and growing "placelessness." One of the volume's authors, David Orr (1999:212–213), described this lamentable condition in this way:

> Most [modern] buildings reflect no understanding of ecology or ecological processes. Most tell its users that knowing where they are is unimportant.

> Most tell its users that energy is cheap and abundant and can be squandered. Most are provisioned with materials and water and dispose of their wastes in ways that tell its occupants that we are not part of the larger web of life. Most resonate with no part of our biology, evolutionary experience, or aesthetic sensibilities.

Recognition of the necessity to change this self-defeating paradigm has led to significant efforts at minimizing and mitigating the adverse environmental and human health impacts of modern development. These efforts have resulted in the growth of the sustainable or green design movement, dramatically illustrated by the extraordinary rise of the U.S. Green Building Council's LEED certification and rating system. While commendable and necessary, these efforts will ultimately be insufficient to achieving the long-term goal of a sustainable, healthy, and well-functioning society.

The basic deficiency of current sustainable design is a narrow focus on avoiding harmful environmental impacts, or what we call *low environmental impact design*. Low environmental impact design, while fundamental and essential, fails to address the equally critical needs of diminishing human separation from nature, enhancing positive contact with environmental processes, and building within a culturally and ecologically relevant context, all basic to human health, productivity, and well-being. These latter objectives are the essence of biophilic design. True and lasting sustainability must combine both low environmental impact and biophilic design, the result being what is called *restorative environmental design* (Kellert 2005). This book, in effect, contends that biophilic design has been until now the largely missing link in current sustainable design. The various chapters attempt to redress this imbalance.

The notion of biophilic design derives from the concept of *biophilia*, the idea that humans possess a biological inclination to affiliate with natural systems and processes instrumental in their health and productivity. Originally proposed by the eminent biologist and one of the volume's authors, Edward O. Wilson, biophilia has been eloquently described by Wilson in this way (1984:35): "To explore and affiliate with life is a deep and complicated process in mental development. To an extent still undervalued . . ., our existence depends on this propensity, our spirit is woven from it, hope rises on its currents." The idea of biophilia is elucidated elsewhere (Wilson 1984, Kellert and Wilson 1993, Kellert 1997), and described in chapters in this volume by Kellert and E. O. Wilson.

Biophilic design is the expression of the inherent human need to affiliate with nature in the design of the built environment. The basic premise of biophilic design is that the positive experience of natural systems and processes in our buildings and constructed landscapes remains critical to human performance and well-being. Various chapters in the volume cite growing scientific evidence to corroborate this assumption in studies of health care, the workplace, childhood development, community functioning, and more. More generally, the authors offer insight and understanding regarding the theory, science, and practice of biophilic design.

Part I of the book focuses on a conceptual understanding of biophilia and biophilic design. Chapters by Kellert, E. O. Wilson, Benyus, Mador, and Salingaros and Masden offer various biological and cultural understandings of the human need to affiliate with natural systems, and how this inclination can be achieved through design of the built environment. The authors address the neglect of the human-nature connection in modern architecture and construction, a condition the eminent architectural historian Vincent Scully described in this way (1991:11): "The relationship of man-made structures to the natural world . . . has been neglected by architecture. . . . There are many reasons for this. Foremost among them . . . is the blindness of the contemporary urban world to everything that is not itself, to nature most of all."

A major cause for this blindness has been the lack of empirical evidence revealing the illogical and self-defeating consequences of designing in adversarial relation to the natural environment. Part II of the book provides much of this needed evidentiary material, particularly the many health and productivity benefits of biophilic design, as well as the harmful consequences of impeding and degrading human contact with natural systems and processes. Chapters by Ulrich, Frumkin, Loftness, and Hartig and colleagues delineate a range of

health, physical, emotional, and intellectual advantages of building and landscape designs that facilitate the positive experience of nature. Additional chapters by Moore and Marcus, Louv, and Pyle and Orr describe the importance of nature in childhood maturation, how to foster this connection through the design of residential and educational settings, and the deleterious and potentially disastrous consequences of doing otherwise.

Part III focuses on the practical challenge of implementing biophilic design, most particularly how to transform conventional and prevailing sustainable design practice. Chapters by Heerwagen and Gregory, Kieran, Bloomer, Hildebrand, Fisk, and Bender provide insight and guidance regarding the architectural expression of biophilic design, focusing largely on the building and site scale. Additional chapters by Beatley and Rose emphasize how to foster the human-nature connection at the neighborhood, community, and urban scales, even what Beatley ambitiously calls the creation of "biophilic cities." The challenge of transforming the process of design and development essential to implementing biophilic design is addressed in chapters by Alex Wilson, Cramer and Browning, and Fox and Berkebile.

We believe this volume will greatly advance our notions of sustainable, biophilic, and restorative environmental design. Still, our efforts remain a work in progress, with much more to learn about the elusive expression of the inherent human need to affiliate with nature in the design and construction of our buildings, landscapes, communities, neighborhoods, and cities.

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Prologue: In Retrospect

Hillary Brown

During a visit to Turkey more than two decades ago, my companions and I shared pilgrimages to that country's Arcadian ruins, the rock-cut underworld of Cappadocia, and other rewarding sights. At one stop along the Aegean coast, we spent the night seaside at a resort community. With construction detritus everywhere, it was in a graceless stage of formation, its platted but unbuilt streets undoing the modesty of the village. A dozen hotels along the beach elbowed for sea frontage, gleaming glass and concrete towers, each straining to trump the other as more formally prominent, more luxuriously endowed.

In contrast, the entry to our hotel was undistinguished, even obscure, a suggestive breach in a white wall, solid for its several-storied height. Over the threshold, we found ourselves within a long narrow courtyard open to the elements. The sky overhead (experienced as one would an artwork by James Turrell—not as passive observer, but as participant) was an azure slash. At the far end, the sky ballooned above what appeared to be a plaza.

We were seduced down this street that was mostly self-shaded and cooled by a gentle updraft. Trees and plantings dotted the surfaces, muting the noise of our progress. Underfoot, the upended and sea worn cobble paving was punctuated with sandstone slabs at the entries to adjacent spaces, texturing our sound as alternatively smooth or gritty down the length of the corridor.

Overhead, the walls were faced with windows and doors that opened onto balconies hanging out over this narrow street, beaming like so many smiles. Most casements were flung open, others still shuttered against the morning. Quite a few were peopled, elbows on sills, whispering shared delight at awakening in this communal scene.

The building was vocalizing, its diverse din a contemporary rendering of an ancient Mediterranean village. From the far end came soft social sounds—footfalls, a child's exclamation, the soft rise and fall of treble and bass voices. Fountains and laughter stippled the air, while clattering silverware broadcast the locale of a café. From here, just as our ears took in the softness of breaking waves, our nostrils detected and eyes at once confirmed the full expanse of the Aegean. Magnifying our senses while buffering us from everything else, the hotel was channeling the sea.

I remember my sense of gratification as well as curious agitation in taking in this unexpected place, an experience of architectural pleasure that resonated as both new and unfathomably familiar. For the first (and since then, only) time I knew, as I turned to my companions and announced with conviction, that a woman had designed this building. To my friends' astonishment, the hotel manager readily confirmed that yes, in fact, a woman-led practice in Istanbul had won the commission.

For years since, I've given thought to that sharp, almost physiological insight, that instant knowing-in-my-bones that arose from a shared design sensibility. Was it how she closed our eyes and ears to the chaos of this beach community, or how she choreographed our movements to dilate the experience in time, intensifying this sensual introduction to the sea? Perhaps it was her preference for socialized space, invoking a primordial practice of *sharing* exquisite places rather than reserving them for private consumption. In setting itself apart, her retreat, after all, recalled the archetypal Islamic caravansary—that protective, walled compound found at intervals along desert trading routes where travelers together sought refreshment and protection. How compelling was this concept, in contrast to the extravagant resorts next door that claimed visual primacy and exclusivity, ignoring the cultural landscape.

Given an emergent environmental consciousness at the time, I now more fully appreciate this architect's ac-

complishment. My ecstatic moment responded to an artistry that was inventive yet contextual—and deeply ecological. Her rendering of bioregion and climate expressed the essence of *genius loci*—the spirit of the place. Rather than facing the private rooms seaward, she spurned convention by turning them inward, unfolding the sea to us as singular, shared experience.

Just as she intensified the revelation of place, this architect refurbished our faculties by exploiting the intelligence and detailed richness of the natural world, using local resources metamorphosed by time and human agency. She distilled natural materials to their elegant simplicity and rightness of fit. As with ecological designers today, nature was employed here as intrinsic to our biological being, a voice converging through several senses. Our wayfinding to the sparkling sea was intensified with textural, acoustic, and olfactory clues.

Today, many of us realize that successfully communicating the ethical imperative of the green design movement will depend on innovative and compelling expression. In this building, long ago, I glimpsed just such an aesthetic of persuasion—one fundamentally place-based and participatory, experienced through all the senses. While then, this distinguishing green voice struck me as gender-specific, I recognize it today as a responsiveness by no means exclusive to women.

Unnamed at the time, such design sensibilities have recently coalesced for me around the word *biophilic* and now raise central questions framed by a book on biophilic design. First and not least is the curious significance of its only recent arrival as a legitimate topic for investigation. Why isn't biophilic design—perhaps succinctly defined as a creative process driven by, or predisposed toward, bio-logic, which seeks to protect and enhance our link with the forces and faces of nature—an obvious and inherent organizing principle of all works of architecture?

In exploring the dimensions, theories, benefits and practicalities of biophilic design, these essays undertake a range of inquiries. In each new building endeavor, as we renegotiate the boundary between man and the elements, what kind of transactions should take place at the interface? How does the wall become a filter that admits beneficial, yet excludes stressful, sensations? How should we frame a window to function as lens, to better focus on nature while providing a controlled aperture for light, air exchange, and thermal conditioning? If human well-being, productivity and health at home, work, or school may be conferred by an occupant's access to daylight, views of vegetation and fauna, wind currents, and diurnal and seasonal information, why aren't these outcomes already a paramount consideration in all building endeavors? Why shouldn't these natural rights (entitlements, really) feature prominently in our building codes and permitting processes?

An investigation of this intentional, affirmative connection between man and nature makes a provocative contribution to the case for sustainable design. Biophilic design is an emerging voice in building green—a chorus increasingly voluble. It is one that attends to the vital shades and nuances of how we experience environments built for life. For today, in a world of impending climate change and species loss, this design sensibility, one more intuitively *biologic* in nature, is taking on ever greater social and political urgency.

PART I

The Theory of Biophilic Design

chapter

1

Dimensions, Elements, and Attributes of Biophilic Design

Stephen R. Kellert

Biophilic design is the deliberate attempt to translate an understanding of the inherent human affinity to affiliate with natural systems and processes—known as biophilia (Wilson 1984, Kellert and Wilson 1993)—into the design of the built environment. This relatively straightforward objective is, however, extraordinarily difficult to achieve, given both the limitations of our understanding of the biology of the human inclination to attach value to nature, and the limitations of our ability to transfer this understanding into specific approaches for designing the built environment. This chapter provides some perspective on the notion of biophilia and its importance to human well-being, as well as some specific guidance regarding dimensions, elements, and attributes of biophilic design that planners and developers can employ to achieve this objective in the modern, especially urban, built environment.

BIOPHILIA AND HUMAN WELL-BEING

As noted, biophilia is the inherent human inclination to affiliate with natural systems and processes, especially life and life-like features of the nonhuman environment. This tendency became biologically encoded because it proved instrumental in enhancing human physical, emotional, and intellectual fitness during the long course of human evolution. People's dependence on contact with nature reflects the reality of having evolved in a largely natural, not artificial or constructed, world. In other words, the evolutionary context for the development of the human mind and body was a mainly sensory world dominated by critical environmental features such as light, sound, odor, wind, weather, water, vegetation, animals, and landscapes.

The emergence during the past roughly 5,000 years of large-scale agriculture, fabrication, technology,

industrial production, engineering, and the modern city constitutes a small fraction of human history, a period that has not substituted for the benefits of adaptively responding to a largely natural environment. Most of our emotional, problem-solving, critical-thinking, and constructive abilities continue to reflect skills and aptitudes learned in close association with natural systems and processes that remain critical in human health, maturation, and productivity. The assumption that human progress and civilization is measured by our separation from if not transcendence of nature is an erroneous and dangerous illusion. People's physical and mental well-being remains highly contingent on contact with the natural environment, which is a necessity rather than a luxury for achieving lives of fitness and satisfaction even in our modern urban society.

Biophilia is nonetheless a "weak" biological tendency that is reliant on adequate learning, experience, and sociocultural support for it to become functionally robust. As a weak biological tendency, biophilic values can be highly variable and subject to human choice and free will, but the adaptive value of these choices is ultimately bound by biology. Thus, if our biophilic tendencies are insufficiently stimulated and nurtured, they will remain latent, atrophied, and dysfunctional. Humans possess extraordinary capacities for creativity and construction in responding to weak biological tendencies, and this ability constitutes in a sense the "genius" of humanity. Yet, this innovative capacity is a two-edged sword, carrying with it the potential for distinctive individual and cultural expression, as well as the potential for self-defeating expression through either insufficient or exaggerated expression of inherent tendencies. Thus, our creative constructions of the human built environment can be either a positive facilitator or a harmful impediment to the biophilic need for ongoing contact with natural systems and processes.

Looking at biophilic needs as an adaptive product of human biology relevant today rather than as a vestige of a now-irrelevant past, we can argue that the satisfaction of our biophilic urges is related to human health, productivity, and well-being. What is the evidence to support this contention? The data is sparse and diverse, but a growing body of knowledge supports the role of contact with nature in human health and productivity. This topic is extensively discussed elsewhere, such as in chapters in this book by Ulrich, Hartig, Frumkin, and others. Still, the following findings are worth noting (summarized in Kellert 2005):

- Contact with nature has been found to enhance healing and recovery from illness and major surgical procedures, including direct contact (e.g., natural lighting, vegetation), as well as representational and symbolic depictions of nature (e.g., pictures).
- People living in proximity to open spaces report fewer health and social problems, and this has been identified independent of rural and urban residence, level of education, and income. Even the presence of limited amounts of vegetation such as grass and a few trees has been correlated with enhanced coping and adaptive behavior.
- Office settings with natural lighting, natural ventilation, and other environmental features result in improved worker performance, lower stress, and greater motivation.
- Contact with nature has been linked to cognitive functioning on tasks requiring concentration and memory.
- Healthy childhood maturation and development has been correlated with contact with natural features and settings.
- The human brain responds functionally to sensory patterns and cues emanating from the natural environment.
- Communities with higher-quality environments reveal more positive valuations of nature, superior quality of life, greater neighborliness, and a stronger sense of place than communities of lower environmental quality. These findings also occur in poor urban as well as more affluent and suburban neighborhoods.

These studies provide scientific support for the ancient assumption that contact with nature is critical to human functioning, health, and well-being. As the psychiatrist Harold Searles concluded some years ago (1960, 117): "The nonhuman environment, far from being of little or no account to human [health and] personality development, constitutes one of the most basically important ingredients of human existence."

RESTORATIVE ENVIRONMENTAL AND BIOPHILIC DESIGN

Unfortunately, the prevailing approach to design of the modern urban built environment has encouraged the massive transformation and degradation of natural systems and increasing human separation from the natural world. This design paradigm has resulted in unsustainable energy and resource consumption, major biodiversity loss, widespread chemical pollution and contamination, extensive atmospheric degradation and climate change, and human alienation from nature. This result is, however, not an inevitable by-product of modern urban life, but rather a fundamental design flaw. We designed ourselves into this predicament and theoretically can design ourselves out of it, but only by adopting a radically different paradigm for development of the modern built environment that seeks reconciliation if not harmonization with nature.

This new design paradigm is called here "restorative environmental design," an approach that aims at both a low-environmental-impact strategy that minimizes and mitigates adverse impacts on the natural environment, and a positive environmental impact or biophilic design approach that fosters beneficial contact between people and nature in modern buildings and landscapes.

Recognition of how much the modern built environment has degraded and depleted the health and productivity of the natural environment prompted the development of the modern sustainable or green design movement, and years of hard work has started to yield significant change in design and construction practices. Unfortunately, the prevailing approach to sustainable design has almost exclusively focused on the low-environmental-impact objectives of avoiding and minimizing harm to natural systems (e.g., Mendler et al. 2006). While necessary and commendable, this focus is ultimately insufficient, largely ignoring the importance of achieving long-term sustainability of restoring and enhancing people's positive relationship to nature in the built environment, what is called here biophilic design. Low-environmental-impact design results in little net benefit to productivity, health, and well-being. Buildings and landscapes, therefore, will rarely be sustainable over time, lacking significant benefits derived from our ongoing experience of nature. Cutting-edge low-environmental-impact technology inevitably becomes obsolete, and when this occurs, will people be motivated to renew and restore these structures? Sustainability is as much about keeping buildings in existence as it is about constructing new low-impact efficient designs. Without positive benefits and associated attachment to buildings and places, people rarely exercise responsibility or stewardship to keep them in existence over the long run.

Biophilic design is, thus, viewed as the largely missing link in prevailing approaches to sustainable design. Low-environmental-impact and biophilic design must, therefore, work in complementary relation to achieve true and lasting sustainability. The major objectives of low-environmental-impact design have been effectively delineated, focusing on goals such as energy and resource efficiency, sustainable products and materials, safe waste generation and disposal, pollution abatement, biodiversity protection, and indoor environmental quality. Moreover, the detailed specification of design strategies to achieve these goals has been incorporated into certification systems such as the U.S. Green Building Council's LEED rating approach.

In contrast, a detailed understanding of biophilic design remains meager (Kellert 2005, Heerwagen 2001). For the remainder of this chapter, therefore, dimensions, elements, and attributes of biophilic design will be described to partially address this need. The following description identifies two basic dimensions of biophilic design, followed by six biophilic design elements, which in turn are related to some 70 biophilic design attributes. This specification can assist designers and developers in pursuing the practical application of biophilic design in the built environment.

The first basic dimension of biophilic design is an *organic or naturalistic* dimension, defined as shapes and forms in the built environment that directly, indirectly, or symbolically reflect the inherent human affinity for nature. Direct experience refers to relatively unstructured contact with self-sustaining features of the natural environment such as daylight, plants, animals, natural habitats, and ecosystems. Indirect experience involves contact with nature that requires ongoing human input to survive such as a potted plant, water fountain, or

aquarium. Symbolic or vicarious experience involves no actual contact with real nature, but rather the representation of the natural world through image, picture, video, metaphor, and more.

The second basic dimension of biophilic design is a *place-based or vernacular* dimension, defined as buildings and landscapes that connect to the culture and ecology of a locality or geographic area. This dimension includes what has been called a sense or, better, spirit of place, underscoring how buildings and landscapes of meaning to people become integral to their individual and collective identities, metaphorically transforming inanimate matter into something that feels lifelike and often sustains life. As René Dubos (1980, 110) argued:

> People want to experience the sensory, emotional, and spiritual satisfactions that can be obtained only from an intimate interplay, indeed from an identification with the places in which [they] live. This interplay and identification generate the spirit of the place. The environment acquires the attributes of a place through the fusion of the natural and human order.

People are rarely sufficiently motivated to act as responsible stewards of the built environment unless they have a strong attachment to the culture and ecology of place. As Wendell Berry (1972, 68) remarked: "Without a complex knowledge of one's place, and without the faithfulness to one's place on which such knowledge depends, it is inevitable that the place will be used carelessly and eventually destroyed." A tendency to affiliate with place reflects the human territorial proclivity developed over evolutionary time that has proven instrumental in securing resources, attaining safety and security, and avoiding risk and danger.

Despite the modern inclination for mobility, most people retain a strong physical and psychological need for calling some place "home." This attachment to territory and place remains a major reason why people assume responsibility and long-term care for sustaining buildings and landscapes. Conversely, lacking a sense of place, humans typically behave with indifference toward the built environment. An erosion of connection to place has unfortunately become a common affliction of modern society—what Edward Relph called "placelessness," and described in the following way (1976, 12):

> If places are indeed a fundamental aspect of existence in the world, if they are sources of security and identity for individuals and for groups of people, then it is important that the means of experiencing, creating, and maintaining significant places are not lost. There are signs that these very means are disappearing and that "placelessness"—the weakening of distinct and diverse experiences and identities of places—is now a dominant force. Such a trend marks a major shift in the geographical bases of existence from a deep association with places to rootlessness.

The two basic dimensions of biophilic design can be related to six biophilic design elements:

- Environmental features
- Natural shapes and forms
- Natural patterns and processes
- Light and space
- Place-based relationships
- Evolved human-nature relationships

These six elements are then revealed in more than 70 biophilic design attributes.

The remainder of this chapter describes these elements and attributes of biophilic design. This description is necessarily brief, due to space limitations, and insufficient. Additionally, this initial formulation will be modified in the future with increasing knowledge, and some of this categorization will inevitably overlap. This classification should, therefore, be viewed as a work in progress. At the end of the chapter, all the design elements and attributes are listed in Table 1.1, and a small number of illustrations are provided.

Environmental Features

The first and most obvious of the biophilic design elements is *environmental features*, involving the use of relatively well-recognized characteristics of the natural world in the built environment. Twelve attributes are identified, including the following:

1. *Color*. Color has long been instrumental in human evolution and survival, enhancing the ability to locate food, resources, and water; identify danger; facilitate visual access; foster mobility; and more. People for good and obvious reasons are attracted to bright flowering colors, rainbows, beautiful sunsets, glistening water, blue skies, and other colorful features of the natural world. Natural colors, such as earth tones, are thus often used to good effect by designers.
2. *Water*. Water is among the most basic human needs and commonly elicits a strong response in people. The famous architectural critic John Ruskin remarked in this regard (Hildebrand 2000, 71)): "As far as I can recollect, without a single exception, every Homeric landscape, intended to be beautiful, is composed of a fountain, a meadow, and a shady grove." Roger Ulrich similarly observed (1993) based on a review of many studies: "Water features constantly elicit especially high levels of liking or preference." The effective use of water as a design feature is complex, well described in the chapter by Mador, and often contingent on such considerations as perceptions of quality, quantity, movement, clarity, and other characteristics.
3. *Air*. People prefer natural ventilation over processed and stagnant air. Important conditions include quality, movement, flow, stimulation of other senses such as feel and smell, and visual appeal despite the seeming invisibility of the atmosphere.
4. *Sunlight*. Daylight is consistently identified as an important and preferred feature by most people in the built environment. The simple use of natural rather than artificial light can improve morale, comfort, and health and productivity. This preference reflects the fact that humans are a largely diurnal animal, heavily reliant on sight for securing resources and avoiding hazard and danger. People depend on visual acuity to satisfy various physical, emotional, and intellectual needs. Additional consideration of the importance of light is addressed in a later section on the more general biophilic design element of light and space.
5. *Plants*. Plants are fundamental to human existence as sources of food, fiber, fodder, and other aspects of sustenance and security. The mere insertion of plants into the built environment can enhance comfort, satisfaction, well-being, and performance.
6. *Animals*. Animals are similarly basic to human existence as sources of food, resources, protection, and companionship, and occasionally as precipitators of fear and danger. Designing animal life into the built environment can be difficult and problematic, although sometimes effective in aviaries, aquaria, and even the presence of free-roaming creatures associated with certain designs like green roofs. Animals in building interiors typically occur in representational rather than literal form, many through the use of ornament, decoration, art, and in stylized and highly metaphorical disguise. The presence of animal forms, nonetheless, often provokes satisfaction, pleasure, stimulation, and emotional interest.
7. *Natural materials*. People generally prefer natural over artificial materials, even when the artificial forms are close or seeming exact copies of natural products. Part of the aversion is likely due to the inability of artificial materials to reveal the organic processes of aging, weathering, and other dynamic features of natural materials, even inorganic forms like stone. The patina of time may provoke an intuitive understanding among some people of the benefits flowing from the movement of nutrients and energies through natural systems.
8. *Views and vistas*. People express a strong and consistent preference for exterior views, especially when the vistas contain natural features and vegetation. These views are often most satisfying when the scale is compatible with human experience—for example, not overly restricted or confined, unfamiliar, or out of scale or proportion (e.g., too large or too high).
9. *Façade greening*. Buildings with vegetative façades, such as ivy walls or green roofs, often provoke interest and satisfaction. This likely reflects the historic benefits associated with organic materials as sources of insulation, camouflaging protection, or even food. Plants on buildings and constructed landscapes can also evoke a powerful vernacular, such as the thatched or vegetative roofs of many cultures.

10. *Geology and landscape.* The compatible connection of buildings to prominent geological features is often an effective design strategy. These structures are sometimes described as rooted or grounded. Frank Lloyd Wright achieved particular success with his Prairie-style architecture in part by creating structures that worked in strong parallel relation to rather than dominating their savanna-type landscape.
11. *Habitats and ecosystems.* Buildings and landscapes that possess a close and compatible relationship to local habitats and ecosystems also tend to be highly effective and preferred. Important ecosystems in this regard are often wetlands, forests, grasslands, and watersheds.
12. *Fire.* Fire in the built environment, while a complicated and difficult design challenge, is often a preferred feature, generally associated with the benefits of heating and cooking. The manipulated experience of fire within building interiors has long been celebrated as a sign of comfort and civilization, providing pleasing qualities of color, warmth, and movement.

Natural Shapes and Forms

The second biophilic design element is *natural shapes and forms*. This element includes representations and simulations of the natural world often found on building façades and within interiors. Eleven attributes are associated with this design element:

1. *Botanical motifs.* The shapes, forms, and patterns of plants and other vegetative matter are a frequent and often important design element of the built environment (Hersey 1999). These representations often mimic or simulate plant forms such as foliage, ferns, cones, shrubs, and bushes, both literally and metaphorically.
2. *Tree and columnar supports.* Trees have also played a vital role in human affairs as sources of food, building material, paper products, heating supply, and other uses. The appearance or simulation of tree-like shapes, especially columnar supports, is a common and often coveted design feature in the built environment. Some of our most appealing structures contain tree forms and shapes that frequently include leaf capitals. When revealed in multiples, they can sometimes suggest a forested setting.
3. *Animal (mainly vertebrate) motifs.* The simulation of animal life is widespread in building interiors and facades, although to a less extent than with plants. The appearance of animal parts is often encountered, such as claws or heads, rather than entire creatures. Animal forms are frequently revealed in highly stylized, fictionalized, and sometime contorted shapes and forms.
4. *Shells and spirals.* Simulations and depictions of invertebrate creatures are widespread design features in the built environment, particularly shell and spiral forms of actual and imagined mollusks. The shapes and forms of bees (and their hives), flies, butterflies, moths, and other insects, as well as spiders (and their webs) and other invertebrates, are also common. Some building designs mimic invertebrate processes, such as the bioclimatic controls of termite mounds, the structural strength of seashells and hives, and the patterns of webs, a subject considered at the end of this section under the topic of "biomimicry," and in the chapter by Benyus.
5. *Egg, oval, and tubular forms.* Egglike and tubular forms are also design elements in some building interiors, facades, and exterior landscapes such as gardens and fountains. These shapes often occur literally and metaphorically, both important expressions of ornament and sometimes for structural purposes.
6. *Arches, vaults, domes.* Arches, vaults, and domes in the built environment resemble or copy forms found in nature, including beehives, nest-like structures, shell forms, and cliffs. These forms can be used for both decorative and functional purposes.
7. *Shapes resisting straight lines and right angles.* Natural shapes and forms are often sinuous, flowing, and adaptive in responding to forces and pressures found in nature. Natural features are thus rarely revealed as straight lines and right angles characteristic of human engineering and manufactured products and structures. The large-scale modern built environment has often been characterized by

standardized and rigid shapes. People nonetheless generally prefer designs that resemble the tendency of organic forms to resist hard mechanical edges, straight lines and angles.

8. *Simulation of natural features.* This attribute reaffirms the tendency to simulate rather than replicate actual natural forms in the built environment. Ornamentation and decoration especially employ imagined forms only vaguely reminiscent of those found in the natural world. These designs are often most successful when they possess a logic that intimates functional features occurring in nature, such as shapes, patterns and processes that suggest structural integrity and adaptive advantage in response to environmental pressures rather than mere superficial decoration.
9. *Biomorphy*. Some interesting architectural forms bear very little resemblance to life forms encountered in nature, yet are clearly viewed as organic. These resemblances to living forms are usually unconscious products of design, sometimes called "biomorphy" (Feuerstein 2002). Powerful examples of biomorphic architecture that provoke observers to impute known animal and plant labels even when the designer did not deliberately create these life-forms include the birdlike shape of Jörn Utzon's Sydney Opera House and the fernlike or less reverently labeled "pregnant whale" of Eero Saarinen's Yale University hockey rink.
10. *Geomorphology.* Some building designs mimic or metaphorically embrace landscape and geology in relative proximity to the structure. This relationship to the ground can lend the appearance of solidity to the built environment, making structures appear integral rather than separate from their geological context.
11. *Biomimicry.* Some successful designs borrow from adaptations functionally found in nature, particularly among other species. Examples include the structural strength and bioclimatic properties of shells, crystals, webs, mounds, and hives, effectively incorporated into the built environment. This tendency has been called "biomimicry" by Janine Benyus, elucidated in her book of this title (Benyus 1997) and connected to biophilic design in a later chapter in this volume. The knowledge of biomimetic properties is growing rapidly and will likely result in a revolution of product development with enormous biophilic design implications.

Natural Patterns and Processes

A third biophilic design element is *natural patterns and processes.* This element emphasizes the incorporation of properties found in nature into the built environment, rather than the representation or simulation of environmental shapes and forms. Fifteen attributes have been identified and are described below, although this complex element is likely to be altered in the future with additional understanding.

1. *Sensory variability.* Human fitness and survival has always required coping with a highly sensuous and variable natural environment, particularly responding to light, sound, touch, smell, and other sensory environmental conditions. Human satisfaction and well-being continue to be reliant on perceiving and responding to sensory variability, especially when this occurs in structured and organized ways within the built environment.
2. *Information richness.* The cognitive richness of the natural world reflects its likely being the most intellectually challenging environment people will ever encounter even in our modern information age. This quality constitutes one of its most beguiling features, and when effectively incorporated into the built environment in actual or metaphorical form can stimulate curiosity, imagination, exploration, discovery, and problem-solving. Most people, therefore, respond positively to buildings and landscapes that possess information richness, variety, texture, and detail that mimic natural patterns when coherently revealed.
3. *Age, change, and the patina of time.* A fundamental feature of the natural world is aging through time, particularly organic forms. This dynamic progression evokes a sense of familiarity and satisfaction among people, despite the eventual occurrence of senescence, death, and decay. A patina of time is characteristic of natural materials, even inorganic ones, and is one reason, as noted above, that artificial

products rarely evoke sustained positive response even when they are exact copies.

4. *Growth and efflorescence.* Growth and development are specific expressions of aging that when found in the built environment typically provoke pleasure and satisfaction. Efflorescence marks the progressive unfolding of a maturational process that when encountered in buildings and landscapes, especially through ornamentation, is often highly appealing (Bloomer 2000). These temporal and transitional attributes often lend a dynamic quasi-living character to the built environment despite its immutable character.
5. *Central focal point.* The navigability of natural landscapes is often enhanced by the presence of a centrally perceived focal point. This point of reference frequently transforms what otherwise is a chaotic setting into an organized one that facilitates passage and way-finding. As the poet Wallace Stevens described (1955): "I placed a jar in Tennessee/ And round it was, upon a hill./ It made a slovenly wilderness/ surround that hill." Many successful buildings and constructed landscapes similarly achieve coherence despite complexity and large scale when a centrally organized reference point has been effectively incorporated.
6. *Patterned wholes.* People respond positively to natural and built environments when variability has been united by integrated and patterned wholes. What may have previously been experienced as inchoate becomes structured in a manner that fosters understanding and often feelings of mastery and control.
7. *Bounded spaces.* Humans have a strong proclivity for bounded spaces. This territorial tendency, over evolutionary time, likely fostered resource exploitation and security. People also value delineated spaces within the built environment, which enhance the recognition of clear and consistent boundaries and place demarcations.
8. *Transitional spaces.* Transitional spaces within and between built and natural environments often foster comfort by providing access from one area to another. Important passageways in the built environment include thresholds, portals, doors, bridges, and fenestration.
9. *Linked series and chains.* Clear physical and temporal movement in both natural and built environments is often facilitated by linked spaces, especially when occurring in connected chains. These relational spaces convey meaning and organization, as well as sometimes a sense of mystery that both stimulates and entices.
10. *Integration of parts to wholes.* People prefer in natural and built environments the feeling that discrete parts comprise an overall whole, particularly when the whole is an emergent property consisting of more than the sum of the individual parts. This integrative quality fosters a feeling of structural integrity, even in complexes of considerable size and detail.
11. *Complementary contrasts.* Meaning and intelligibility, as well as interest and stimulation, in natural and constructed settings often reveal the blending of contrasting features in complementary fashion. This can occur through the compatible rendering of seeming opposites, such as light and dark, high and low, and open and closed.
12. *Dynamic balance and tension.* The dynamic balancing of different and sometimes contrasting forms often fosters a sense of strength and durability in both natural and built environments. This blending of varying forces often produces a quality of creative tension that transforms static forms into organic-like entities.
13. *Fractals.* Elements in nature are rarely if ever exact copies of one another, even among highly related entities. Snowflakes or leaves of a single species or tree may be highly similar but never the same. Orderly variation on a basic pattern is the norm, whether it be thematic diversity based on size, or spatial or temporal scale. Related and similar forms are often called "fractals," and these patterns are found in some of our most successful buildings and landscapes. These structures frequently include repeated but varying patterns of a basic design, such as ornamentation in parallel or closely linked rows that differ slightly from one another.
14. *Hierarchically organized ratios and scales.* Successful natural and built forms often occur in hierarchically connected ways, sometimes arithmetically or geometrically related. This thematic congruence

can facilitate the assimilation of highly complex patterns that otherwise might be experienced as overwhelmingly detailed or even chaotic. Arithmetic and geometric expressions of this tendency in both natural and built settings include the golden proportion and the Fibonacci ratio (Portoghesi 2000).

Light and Space

A fourth biophilic design element is *light and space*. Twelve design attributes of this element follow, seven focusing on qualities of light and five focusing on spatial relationships:

1. *Natural light.* This attribute includes the effects of daylighting as previously described, as well as inclusion of the full color spectrum of natural light. Chapters by Loftness and Frumkin note studies showing that natural light is both physically and psychologically rewarding to people, frequently contributing to their health, productivity, and well-being in the built environment.
2. *Filtered and diffused light.* The benefits of natural light are often enhanced by modulating daylight, particularly by mitigating the effects of glare. Filtered or diffused sunlight can also stimulate observation and feelings of connection by providing a variable and mediated connection between spaces, particularly inside and outside areas such as described in the chapter by Bloomer.
3. *Light and shadow.* The complementary contrast of light and dark spaces can produce significant satisfaction in both buildings and landscapes. The creative manipulation of light and shadow can foster curiosity, mystery, and stimulation. This attribute likely evolutionarily enhanced human movement and the ability to discern objects over long distances, particularly from a protected refuge.
4. *Reflected light.* Lighting designs are frequently enhanced by light reflecting off surfaces such as light-colored walls, ceilings, and reflective bodies like water. Functional benefits include mitigation of glare, enhanced penetration of light into interior spaces, and spying resources at a distance.
5. *Light pools.* People are often drawn into and through interior spaces by the presence of pools of connected light. Light pools can assist movement and way-finding by providing lighted patches across shadowed or obscured areas such as a forest or darkened halls and passageways. Light pools can also foster feelings of security and protection, such as a lighted hearth.
6. *Warm light.* The perception of warmly lit areas, often islands of modulated sunlight surrounded by darker spaces, can enhance the feeling of a nested, secure, and inviting interior.
7. *Light as shape and form.* The manipulation of natural light can create stimulating, dynamic, and sculptural forms. Beyond the aesthetic pleasure, these shapes facilitate mobility, curiosity, imagination, exploration, and discovery.
8. *Spaciousness.* People prefer feelings of openness in natural and built environments, especially when it occurs in complementary relation to sheltered protected refuges at the surrounding edges. Effective designs often include spacious settings in close alliance with smaller spaces, which in contemporary architecture can often be encountered in airports, train stations, and some commercial and educational buildings.
9. *Spatial variability.* Spatial variability fosters emotional and intellectual stimulation. Spatial diversity is often most effective when in complementary relation to organized and united spaces.
10. *Space as shape and form.* Space can be creatively manipulated to convey shapes and forms. This effect can add beauty to the built environment, which stimulates interest, curiosity, exploration, and discovery.
11. *Spatial harmony.* The manipulation of space in the built environment tends to be most effective when it blends light, mass, and scale within a bounded context. This achievement evokes a sense of harmony, which fosters a sense of security and facilitates movement within diverse settings.
12. *Inside-outside spaces.* Appealing interior spaces in the built environment often appear connected to the outside environment. These areas also mark the transition of nature with culture. Important design forms in the built environment that evoke this quality include colonnades, porches, foyers, atriums, and interior gardens.

Place-Based Relationships

A fifth biophilic design element is *place-based relationships*. This element refers to the successful marriage of culture with ecology in a geographical context. The connection of people to places reflects an inherent human need to establish territorial control, which during the long course of our species' evolution facilitated control over resources, attaining safety, and achieving security. Locational familiarity—the yearning for home—remains a deeply held need for most people. Eleven attributes of place-based relationships are described, the last (placelessness) being the antithesis of the others rather than a stand-alone attribute.

1. *Geographic connection to place.* Secure feelings of connection to the geography of an area often foster feelings of familiarity and predictability. This can be achieved by emphasizing prominent geological features associated with the siting, orientation, and views of buildings and landscapes.
2. *Historic connection to place.* Meaningful relation to place often marks the passage of time, which fosters a sense of participation and awareness of an area's culture and collective memory. Buildings and landscapes that elicit this continuity with the past encourage the belief that the present and future are meaningfully linked to the history of a place.
3. *Ecological connection to place.* Places are sustained by an affirmative connection to ecology, particularly prominent ecosystems such as watersheds and dominant biogeographical features (e.g., mountains, deserts, estuaries, rivers, and oceans). The design of the built environment inevitably refashions nature, but this can occur in ways that do not diminish the overall biological productivity (e.g., nutrient flux), biodiversity, and ecological integrity of proximate ecological communities. Humans, like any ecologically transformative organism (e.g., elephants on the savanna, sea otters in a kelp bed), can add as well as subtract value from their natural systems. The design of the built environment can, therefore, aspire to achieve net ecological productivity.
4. *Cultural connection to place.* Cultural connection to place integrates the history, geography, and ecology of an area, becoming an integral component of individual and collective identity. The need for culture is a universal human need, sustained over time by repetition, normative events, and the architectural heritage of a people, particularly its treasured and distinctive vernacular forms.
5. *Indigenous materials.* A positive relation to place is generally enhanced by the utilization of local and indigenous materials. Native resources can provide a vivid and resonant reminder of local culture and environment, as well as require less energy for manufacture and transport.
6. *Landscape orientation.* Buildings and landscapes that compatibly connect to the local environment contribute to a sense of place. These constructions typically emphasize landscape features such as slope, aspect, sunlight, wind direction, and others that take advantage of prevailing biometeorological conditions. This orientation to landscape frequently evokes a sense of being a part of and embedded within local settings, rather than being separated from them.
7. *Landscape features that define building form.* Landscape features can embellish and distinguish building form, particularly prominent geological features, natural objects, and water. The built environment can, therefore, integrate with rather than be isolated from its biophysical context. When this fails to occur, even extraordinary buildings can be perceived as standing apart, perhaps impressive products of human engineering but largely abstract forms divorced from context and barren.
8. *Landscape ecology.* Effective place-based designs reinforce landscape ecology over the long term. This can be achieved through design that considers landscape structure, pattern, and process such as ecological connectivity, biological corridors, resource flows, biodiversity, optimal scale and size, ecological boundaries, and other parameters of functioning natural systems (Dramstad et al. 1996).
9. *Integration of culture and ecology.* The fusion of culture with ecology fosters long-term sustainability. The result marks the point where nature and humanity are positively transformed and mutually enriched by their association. When this occurs, buildings and landscapes often provoke considerable

loyalty, responsibility, and stewardship among the people who reside nearby.

10. *Spirit of place.* The spirit of a place signifies a level of commitment and meaning that people extend to both natural and built environments when they become cherished components of individual and collective identity, more than simply inanimate matter. The spirit of a place metaphorically signifies the built environment having become life-life and serving as the motivational basis for long-term stewardship and responsibility. While not technically alive, these structures and places give rise to and sustain human culture and ecology over time.
11. *Avoiding placelessness.* "Placelessness" is the antithesis of place-based design, to be avoided whenever possible. One of the insidious and damaging effects of much modern architecture has unfortunately been the divorce of design from connection to the culture or ecology of place. This corrosive separation of the built environment from its biocultural context has resulted in the decline of human-nature relationships and environmental sustainability.

Evolved Human-Nature Relationships

The sixth and final biophilic design element is *evolved human-nature relationships*. The term is somewhat misleading, as all the described biophilic design elements presumably reflect biologically based human affinities for the natural environment. The attributes described in this section, however, more specifically focus on fundamental aspects of the inherent human relationship to nature. Twelve attributes are described, the last eight of which are derived from a typology of environmental values developed by the author and described elsewhere (Kellert 1996, 1997):

1. *Prospect and refuge.* Refuge reflects a structure or natural environment's ability to provide a secure and protected setting. In the built environment, this often occurs through the design of comfortable and nurturing building interiors and secreted landscape places. Prospect, on the other hand, emphasizes discerning distant objects, habitats and horizons, evolutionarily instrumental in locating resources, facilitating movement, and identifying sources of danger. Some of our most satisfying buildings and landscapes capture the complementary relation of prospect with refuge (Hildebrand 2000, Appleton 1975).
2. *Order and complexity.* Order is achieved in the built or natural environment by imposing structure and organization. Extreme order often results in repetition, monotony, and boredom. By contrast, complexity reflects the occurrence of detail and variability. Excessive complexity can also be troublesome, making it difficult to assimilate detail and sometimes leading to a sense of chaos. Designs that effectively meld order with complexity tend to be successful, stimulating the desire for variety but in ways that seem controlled and comprehensible.
3. *Curiosity and enticement.* Curiosity reflects the human need for exploration, discovery, mystery, and creativity, all instrumental in problem solving (Kaplan et al. 1998). Enticement fosters curiosity. These complementary tendencies can engage the flywheel of human intellect and imagination. Some of our most effective buildings and landscapes foster curiosity, exploration, and discovery of natural process and diversity.
4. *Change and metamorphosis.* Change is a constant in both natural and human systems, reflected in the processes of growth, maturation, and metamorphosis (Bloomer 2000). Many powerful designs capture this dynamic and developmental quality, where one form or state appears to flow into another in a quasi-evolutionary sequence.
5. *Security and protection.* A fundamental objective of the built environment is ensuring protection from threatening forces in nature. Yet, the most successful designs over the long run never accomplish this need at the expense of other equally legitimate environmental values. Security in the built environment must not excessively insulate or isolate people from the natural world.
6. *Mastery and control.* Buildings and constructed landscapes reflect the human desire for mastery and control over nature. When accomplished with moderation and respect, mastering nature facilitates the satisfactory expression of human ingenuity and

cleverness that fosters self-confidence and self-esteem.

7. *Affection and attachment.* Affection for the natural world has been a critical component in engendering the human capacities for bonding and attachment, important in a largely social creature. Buildings and landscapes that elicit strong emotional affinities for nature are typically recipients of lasting loyalty and commitment.
8. *Attraction and beauty.* The aesthetic attraction to nature is one of the strongest inclinations of the human species. This biologically encoded tendency has been instrumental in fostering the capacities for curiosity, imagination, creativity, exploration, and problem solving. Some of our most successful buildings and landscapes foster an aesthetic appreciation for natural process and form.
9. *Exploration and discovery.* Nature is the most information-rich and intellectually stimulating environment that people ever encounter. Buildings and constructed landscapes that facilitate opportunities for exploration and discovery of natural process elicit considerable interest and appreciation, even when these environmental features are largely revealed in representational ways.
10. *Information and cognition.* Intellectual satisfaction and cognitive prowess can be fostered through designs that emphasize the complexity of natural shapes and forms. This can be achieved through the direct and indirect experience of nature, as well as by the creative use of ornamentation in the built environment that fosters critical thinking and problem solving.
11. *Fear and awe.* It may seem odd to emphasize negative and unwanted feelings such as fear and aversion of nature as components of biophilic design. Yet, protecting ourselves from threatening elements of the natural world has always been a primary objective of the built environment. Fear of nature can also be a motivational basis for designing peril and adventure into the built environment, such as overhanging precipices or proximity to fearsome forces like rushing water. Feelings of awe for the natural world can further combine reverence with fear, and some of our most celebrated structures achieve this effect through extolling majestic natural features that engender an appreciation for powers greater than ourselves.
12. *Reverence and spirituality.* Some of our most cherished buildings similarly affirm the human need for establishing meaningful relation to creation. These designs provoke feelings of transcendence and enduring connection that defy the aloneness of a single person isolated in space and time. Structures that achieve this reverential feeling of connection are also typically sustained generation after generation.

CONCLUSION

Six biophilic design elements and roughly 70 attributes have been described, and are summarily listed in Table 1-1. A small number of illustrations are provided at the chapter's conclusion depicting some of these design features. This categorization is a work in progress, which inevitably will be modified and improved over time.

All design of the built environment, including the biophilic desire to harmonize with nature, reflects what René Dubos called the active "wooing of the earth" (Dubos 1980). This objective, in other words, results in some degree of deliberate refashioning of nature to satisfy human needs, but in ways that celebrate the integrity and utility of the natural world. Thus, human intervention, if practiced with restraint and respect, can avoid arrogance and environmental degradation. With humility and understanding, effective biophilic design can potentially enrich both nature and humanity. As Dubos remarked (1980, 68):

> Wooing of the earth suggests the relationship between humankind and nature [can] be one of respect and love rather than domination. The outcome of this wooing can be rich, satisfying, and lastingly successful if both partners are modified by their association so as to become better adapted to each other.