PART I

The Theory of Biophilic Design

chapter

1

Dimensions, Elements, and Attributes of Biophilic Design

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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.

TABLE 1-1 Elements and Attributes of Biophilic Design

Environmental features	Natural shapes and forms	Natural patterns and processes
Color	Botanical motifs	Sensory variability
Water	Tree and columnar supports	Information richness
Air	Animal (mainly vertebrate) motifs	Age, change, and the patina of time
Sunlight	Shells and spirals	Growth and efflorescence
Plants	Egg, oval, and tubular forms	Central focal point
Animals	Arches, vaults, domes	Patterned wholes
Natural materials	Shapes resisting straight lines and right angles	Bounded spaces
Views and vistas		Transitional spaces
Façade greening	Simulation of natural features	Linked series and chains
Geology and landscape	Biomorphy	Integration of parts to wholes
Habitats and ecosystems	Geomorphology	Complementary contrasts
Fire	Biomimicry	Dynamic balance and tension
		Fractals
		Hierarchically organized ratios and scales

Light and space	Place-based relationships	Evolved human-nature relationships
Natural light	Geographic connection to place	Prospect and refuge
Filtered and diffused light	Historic connection to place	Order and complexity
Light and shadow	Ecological connection to place	Curiosity and enticement
Reflected light	Cultural connection to place	Change and metamorphosis
Light pools	Indigenous materials	Security and protection
Warm light	Landscape orientation	Mastery and control
Light as shape and form	Landscape features that define building form	Affection and attachment
Spaciousness		Attraction and beauty
Spatial variability	Landscape ecology	Exploration and discovery
Space as shape and form	Integration of culture and ecology	Information and cognition
Spatial harmony	Spirit of place	Fear and awe
Inside-outside spaces	Avoiding placelessness	Reverence and spirituality

1. ENVIRONMENTAL FEATURES

Figure 1-1: Jubilee Campus, University of Nottingham, Nottingham, England. This design by Hopkins Architects effectively incorporates water as a positive experiential and low-impact (e.g., evaporative cooling) element.

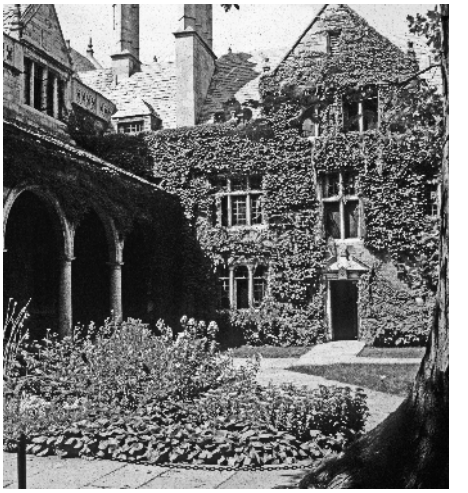


Figure 1-2: University of Michigan law quadrangle. The ivy-covered walls provide a pleasing integration of vegetation into the building façade.

2. NATURAL SHAPES AND FORMS

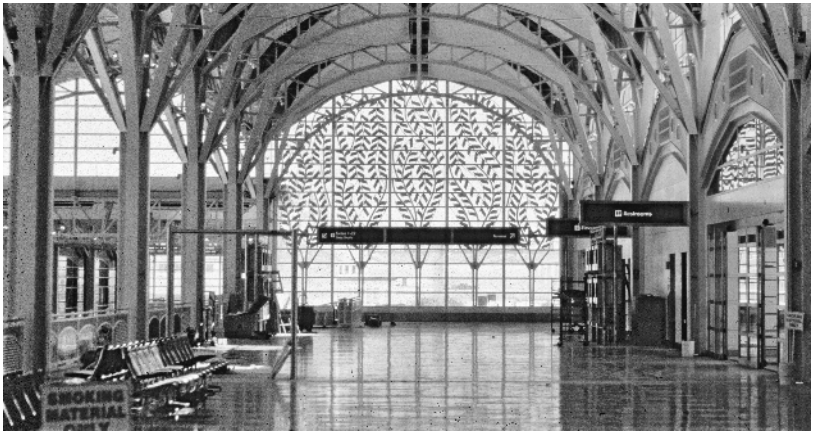


Figure 1-3: Foliated sculpture by Kent Bloomer, Ronald Reagan Airport terminal. This metaphorical representation of nature draws well on instinctual affinities for vegetative forms.

Figure 1-4: Sydney Opera House, Jörn Utzon, architect. This building dramatically juxtaposes bird- and sail-like forms against the waters of Sydney Harbour.

3. NATURAL PATTERNS AND PROCESSES

Figure 1-5: New York City building façade. The shapes in this façade draw on foliated patterns and fractal geometries encountered in nature.

Figure 1-6: Harkness Tower, Yale University. This tower mimics many organic features often encountered in Gothic architecture.

4. LIGHT AND SPACE

Figure 1-7: San Francisco hotel lobby. This lobby combines the sculptural qualities of light with a highly organic space.

Figure 1-8: Genzyme Building, Cambridge, Massachusetts, Behnisch, Behnisch and Partner, architects. This office building innovatively includes light, water, and vegetation in a deep building interior, purportedly resulting in enhanced worker comfort, morale, and productivity.

5. PLACE-BASED RELATIONSHIPS

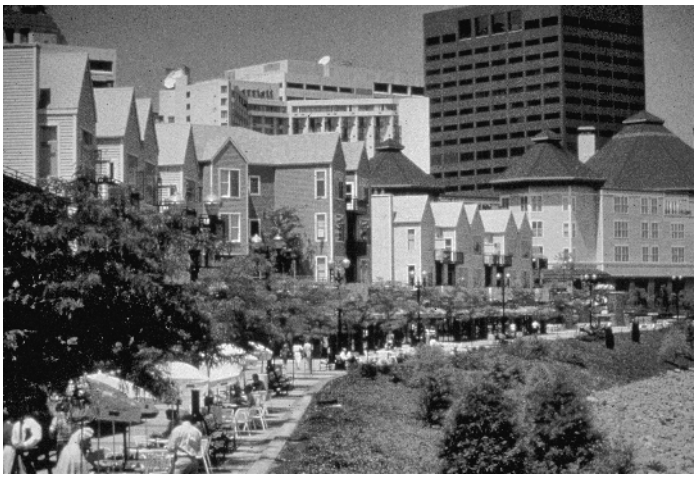
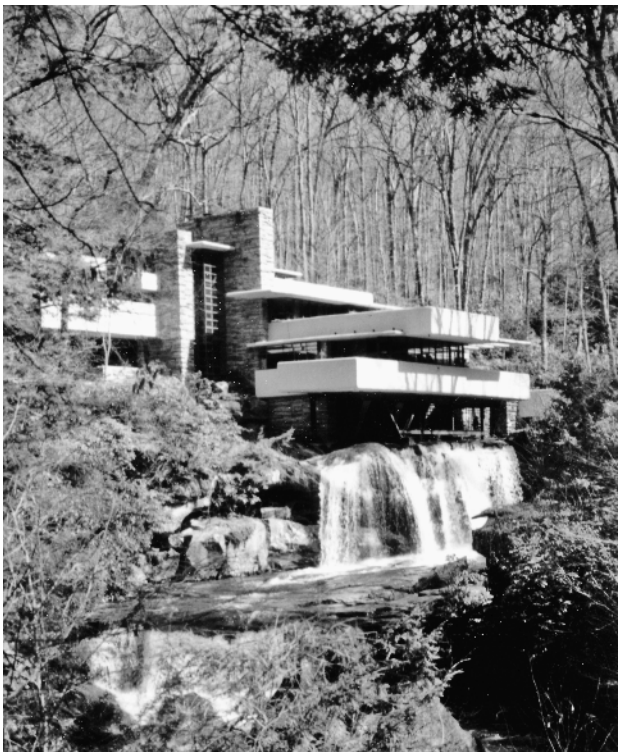


Figure 1-9: Mixed-used development, Portland, Oregon. The combined residential and commercial uses along a restored and revegetated riverfront has engendered a renewed sense of connection to place.

Figure 1-10: Bastille viaduct or Promenade Plantée, Paris. This elevated linear greenway situated on a former railroad line has stimulated commercial and social activity in this section of Paris.

6. EVOLVED RELATIONSHIPS TO NATURE



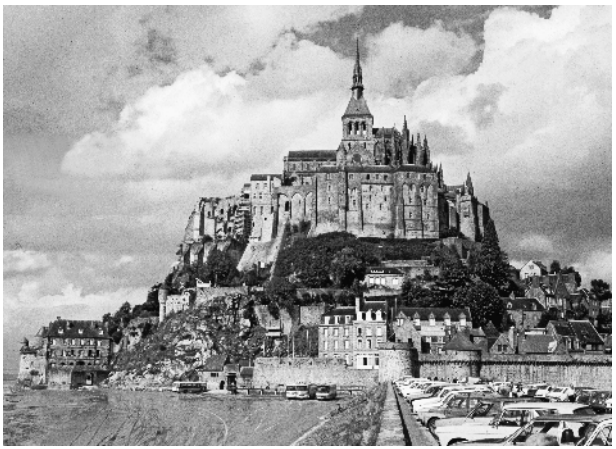


Figure 1-11: Fallingwater, Frank Lloyd Wright, architect. The strong appeal of this residence partly reflects its prominent prospect and refuge elements, as well as its connection to the hillside and adjacent stream course.

Figure 1-12: Mont-Saint-Michel, France. The timeless fascination of this structure derives in part from its powerful combination of order and complexity against a dramatic hill and ocean backdrop.

REFERENCES

Appleton, J. 1975. *The Experience of Nature*. London: Wiley.

Benyus, J. 1997. *Biomimicry: Innovation Inspired by Nature*. New York: Murrow.

Berry, W. 1972. *A Continuous Harmony: Essays Cultural and Agricultural*. New York: Harcourt.

Bloomer, K. 2000. *The Nature of Ornament: Rhythm and Metamorphosis in Architecture*. New York: Norton.

Dramstad, W., J. Olson, R. Forman. 1996. *Landscape Ecology Principles in Landscape Architecture and Land-Use Planning*. Washington, DC: Island Press.

Dubos, R. 1980. *Wooing of the Earth*. New York: Scribner.

Feuerstein, G. 2002. *Biomorphic Architecture: Human and Animal Forms in Architecture.* Stuttgart: Axel Menges.

Heerwagen, J., and B. Hase. 2001. "Building Biophilia: Connecting People to Nature." *Environmental Design and Construction*. March–April: 30–34.

Hersey, G. 1999. *The Monumental Impulse: Architecture's Biological Roots*. Cambridge, MA: MIT Press.

Hildebrand, G. 2000. *The Origins of Architectural Pleasure*. Berkeley: University of California Press.

Kaplan, S., R. Kaplan, and R. Ryan. 1998. *With People in Mind: Design and Management of Everyday Life*. Washington, DC: Island Press.

Kellert, S. 1996. *The Value of Life: Biological Diversity and Human Society*. Washington, DC: Island Press.

Kellert, S. 1997. *Kinship to Mastery: Biophilia in Human Evolution and Development.* Washington, DC: Island Press.

Kellert, S. 2005. *Building for Life: Designing and Understanding the Human-Nature Connection*. Washington, DC: Island Press.

Kellert, S., and J. Heerwagen. Forthcoming. "Nature and Healing: The Science, Theory, and Promise of Biophilic Design." In *Sustainable Architecture for Health*, edited by G. Vittori and R. Guenther.Hoboken, NJ: Wiley.

Kellert, S., and E. O. Wilson, eds. 1993. *The Biophilia Hypothesis.* Washington, DC: Island Press.

Mendler, S., W. Odell, M. Lazarus. 2006. *The HOK Guidebook to Sustainable Design.* Hoboken, NJ: Wiley.

Portoghesi, P. 2000. *Nature and Architecture.* Milan: Skira.

Relph, E. 1976. *Place and Placelessness.* London: Pion.

Searles, H. 1960. *The Nonhuman Environment in Normal Development and in Schizophrenia*. New York: International Universities Press.

Stevens, W. 1955. *Collected Poems.* New York: Knopf.

Ulrich, R. 1993. "Biophilia, Biophobia, and Natural Landscapes." In *The Biophilia Hypothesis*, edited by S. Kellert and E. O. Wilson. Washington, DC: Island Press.

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