Neuroscience, the Natural Environment, and Building Design.

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Abstract: *The human mind is split between genetically-structured neural systems, and an internally-generated worldview. This split occurs in a way that can elicit contradictory mental processes for our actions, and the interpretation of our environment. Part of our perceptive system looks for information, whereas another part looks for meaning, and in so doing gives rise to cultural, philosophical, and ideological constructs. Architects have come to operate in this second domain almost exclusively, effectively neglecting the first domain. By imposing an artificial meaning on the built environment, contemporary architects contradict physical and natural processes, and thus create buildings and cities that are inhuman in their form, scale, and construction. A new effort has to be made to reconnect human beings to the buildings and places they inhabit. Biophilic design, as one of the most recent and viable reconnection theories, incorporates organic life into the built environment in an essential manner. Extending this logic, the building forms, articulations, and textures could themselves follow the same geometry found in all living forms. Empirical evidence confirms that designs which connect humans to the lived experience enhance our overall sense of wellbeing, with positive and therapeutic consequences on physiology. We offer a theory to help understand and explain these effects.*

1. Introduction.

Our mental processes enable us to interact with and adapt to our environment. We instinctively crave physical and biological connection to the world. The human perceptual mechanisms through which these processes work establish our relationship and response to both architecture and the built environment. The basis for this interaction is human nature itself: the end result of the evolution of our neural system in response to external stimuli such as the informational fields present in the natural environment.

Humans, seeking shelter from the elements, are compelled to construct buildings and cities. Historically, the form of those structures arose from within the material logic of their immediate surroundings, and from the spatial ordering processes of their minds (through biological necessity). Utilizing what was at hand to give structure to existence, people instinctively constructed places that provided the constituent information, form, and meaning that their sense of wellbeing required. Design decisions occurred as a natural extension of the neurological processes that make us alive and human.

Not consciously aware of the nature of these processes, humankind simply built its buildings and cities in this manner without question for millennia. Over the course of time, however, the relationship to the physical world began to take on a greater complexity through applied meaning: i.e. local mythology, symbolisms, and social structures. As the *process-of-building* was usurped by the *process-of-design*, architecture as a tectonic expression of innate human ideas about form, space, and surface became more difficult to grasp. People's relationship to the physical world was further complicated with 20th-Century advances in technology and industrialization.

This is clearly evident in the practice of architecture today. Following several centuries of refinement and addition to the traditional vocabulary of architecture, the design process, once the exclusive domain of the Master Builder, has taken root in a different soil altogether. As architecture shifted from the domain of craft into the intellectual property of the University, the study of architecture began to align itself with other academic disciplines, although incompletely. While architecture mimicked the academic realm of philosophy, it reinvented itself as a new discipline detached from its own evolution. Over time, architects effectively disconnected themselves from their history, which was henceforth treated more like archaeology: as interesting, but irrelevant to present-day design concerns. In the years that followed, architectural design, and the study of design methodologies, were all but severed from those processes that had served for millennia to render the built environment as something intrinsically human.

We contend here that processes underlying human engagement with the physical world support biophilic design as a reconnective methodology. Furthermore, we believe that this knowledge can guide current and future architecture toward a more intrinsically human expression. The following is an overview of our exposition. Related scientific research establishes the positive physiological effects of particular types of environment, such as those constructed within the concept of biophilia (Section 2). These respond in their form to the human need for intimate contact with living forms. Explaining biophilia (Section 3), we outline two distinct, convergent approaches to its interpretation and architectural implementation. This body of knowledge is then contextualized within a broad, unifying movement. We review techniques (Section 4) that seek to establish a method or process for architectural design relating directly to human sensibilities. A body of compelling research supports this way of thinking about the built environment. Practical information given here and in Appendix I is meant to help and inspire architects wishing to implement these ideas. As this dialogue on re-connecting the built environment to humans and their everyday lives continues to grow, we are confident that the discipline of biophilic design will find its way into the mainstream education and practice of architecture.

In the remaining sections of this chapter we will discuss how human nature directly

affects architecture. The key here is informational connectivity, which our research establishes as the mechanism by which humans relate to biological forms and connect with the physical world. We define three different conceptions of human beings: mechanical, biological, and transcendental (Sections 5 to 11). The abstract human being of the 20th century (Section 6) is an ideal inhabitant of places that are designed according to strictly formal criteria. In contrast, the biological human being of both the pre-industrial era and the new millennium requires a particular type of sensory feedback from the environment (Section 7). This type of feedback/information is becoming harder and harder to find in contemporary cities. We will show how the precise nature of structures that provide the appropriate feedback can be discovered in the unselfconscious traditional and vernacular built environments (Section 8). We identify a part of this stored information with "expert knowledge" that supports *Pattern Languages* as an essential design tool. Furthermore, we argue that when human beings experience emulated biological qualities such as in human-computer interfaces, they engage in a natural way (Section 9). This is the same type of connection observed with animals such as pets, and suggests the possibility of an intimate neurological connection with architecture.

Towards the end of the chapter, we delve into the highest conception of human nature: the transcendent human being possesses qualities that seem to transcend our biological nature (Section 10). We contend that transcendence is generated via connection through higher-level neurological processes. Those qualities make possible our greatest intellectual and creative achievements. Philosophy and religion enter into this discussion unavoidably. Accepting this ultimate capacity of human beings leads us to questions about re-creating architecture that transcends its materiality (Section 11). Certain buildings — some of them religious, others quite modest — achieve such an intense degree of connection that they can induce a state of healing in us. The informational content in this type of structure is simply so successful in its conception that it connects more directly to neurological processes. It requires far less translation and interpretation by the mind and thus presents itself as inspired or divine. Our aim is to understand how that mechanism arises, as it relates to the concept of biophilic design.

Finally, Appendix I gives a list of practical design techniques. These are meant to help practitioners who might wish to engage architectural design in a more human manner. With the addition of some forward-thinking speculations, we consider how computers and robots might create those human-like qualities in architecture that once breathed life into the built environment. Appendix II summarizes several patterns from Alexander's *Pattern Language* (Alexander *et. al.*, 1977) that are relevant to biophilic design. These practical design patterns anticipate and support the message of this Chapter.

2. Biologically-based design.

The positive effects of biophilic design must be understood in architectural terms: as form and form-making principles, and structural systems. Biologically-based design utilizes observed effects, and tries to document them into an empirical and tested body of knowledge. At the same time, an extensive research program is beginning to uncover the deeper causes for these effects: i.e., a possible innate reaction to the specific geometry of natural forms, detail, hierarchical subdivisions, color, etc. Since this project is far broader

than the traditional study of architecture, designers must actively solicit help from other disciplines whose knowledge can help to explain human response to design. It is essential not to be partial in any way, since, in addition to known factors, there are clearly unknown factors playing a role yet to be discovered.

Recent investigations lead us inescapably to the fact that we engage emotionally with the built environment through architectural forms and surfaces. We experience our surroundings no differently than we experience natural environments, other living creatures, and other human beings. We relate to details, surfaces, and architectural spaces in much the same way as we relate to domestic animals such as our pets. The mechanism through which we engage with subjects outside ourselves relies on a connection established via information exchange. Our neurological mechanism reacts to the information field (the transmission component), while inducing a reaction in the state of our body (the physiological component). Some of the highest levels of sensory connection to the built environment have been evidenced in the great buildings and urban spaces of the past (Alexander, 2002-2005; Salingaros, 2005; 2006). Both natural and built environments possess intrinsic qualities that enable such a strong connection, and which in turn can be healing. This works through the sense of wellbeing established and maintained in the life of those who engage with such a structure. Great architects in the past were better able to discern those qualities, and to reproduce them in their buildings, because they were more engaged with their immediate surroundings.

What we are depends on the natural environment that shaped our bodies and senses (Kellert, 2005; Kellert & Wilson, 1993; Orians & Heerwagen, 1992). Far from being able to liberate our modern selves from our historical development, we inherit our biological origin in the structure of our mind and body. Nature has built on top of this over successive millennia, in increasing layers of sophistication. Evolution works by using what is already there, extending and recombining existing pieces to make something new. We thus depend on the presence of certain determinant qualities in the environment not only for our existence, but equally for our sense of belonging and wellbeing. Denying this genetic dependence is akin to denying our necessity for food and air. The typologies of traditional and vernacular architectures are predicated on biological necessity. They are not romantic expressions (as some would have us believe), but in fact a primal source of neurological nourishment.

A new chapter in scientific investigation is beginning to document environmental factors that affect our physiological wellbeing. Going beyond the century-old debates on aesthetics, a neurological basis for aesthetic response is now being established (Ramachandran & Rogers-Ramachandran, 2006). The mechanism for neurological nourishment was recently discovered in studies using Functional Magnetic Resonance Imaging. Humans have an innate hunger for certain types of information: the circuits for this have been associated with the brain's pleasure centers, which also control the reduction of pain (Biederman & Vessel, 2006). It is easy to hypothesize that this neurophysiologic mechanism is the result of an advantageous evolutionary adaptation.

A growing amount of research finds that fractal qualities in our environment (i.e., ordered details arranged in a nested scaling hierarchy) contribute positively to human wellbeing (Hagerhall, Purcell & Taylor, 2004; Taylor, 2006; Taylor *et. al.*, 2005). Gothic architecture is intrinsically fractal, and has been conjectured to be an externalization of

the fractal patterns of our brain's neural organization (Goldberger, 1996). The parallel between built fractal patterns and possible cerebral organization is too strong to be a coincidence (Salingaros, 2006). This idea is supported independently by the way we perceive and find meaning in patterns in our environment (Kellert, 2005; Salingaros, 2006). It is no surprise then that humans build those patterns into their creations. Investigations of all traditional architectural and urban forms and ornamentation confirm their essentially fractal qualities (Crompton, 2002; Salingaros, 2005; 2006).

Another direction of research has uncovered undisputed clinical advantages (faster hospital healing) of natural environments, including artificial environments mimicking geometrical qualities of natural environments (Frumkin, 2001; Ulrich, 1984; 2000). Pain relief in hospital settings is significantly improved by viewing natural (or videos of natural) environments (Tse *et. al.*, 2002), thus confirming the link between specific types of informational input and pain reduction. These developments have sparked the interest of organizations concerned with improving the positive human qualities of their spaces. Much of this research has started to be applied in the field of interior design rather than architecture (Augustin & Wise, 2000; Wise & Leigh-Hazzard, 2002). There are principally two reasons for this: first, interiors are much easier to manipulate than entire buildings; and second, environments for work, leisure, or health care can make a more immediate and substantive difference in human wellbeing and performance.

Reviewing the positive effect that fractals and natural complexity have on humans, Yannick Joye (2006; 2007a; 2007b) reinforces our own conclusions on the essential "hard-wired" nature of the process. This is not the result of a conscious response to recognizing fractal or complex patterns in the environment: it is built into our neural system. Reaction to a neurologically-nourishing environment is physiological (i.e. emotional) rather than intellectual. There is mounting evidence of an innate information-processing system that has evolved along with the rest of our physiology (Joye, 2006; 2007a; 2007b). This system is acutely tuned to the visual complexity of the natural environment, specifically to respond positively to the highest levels of organized complexity (Salingaros, 2006).

Some researchers concentrate on human response to fractal qualities, whereas others measure the benefits of the complex geometry found in natural forms. Fractals are an important component of this effect, but by no means represent the full gamut of connective qualities. Additional geometrical properties of natural/biological forms clearly contribute to a positive physiological response in humans (Alexander, 2002-2005; Enquist & Arak, 1994; Kellert, 2005; Klinger & Salingaros, 2000; Salingaros, 2005; 2006). Symmetry — more precisely, a hierarchy of subsymmetries on many distinct scales — plays a crucial role. The overall perceived complexity is better understood using a multi-dimensional model rather than the simplistic one-dimensional model of plainness versus complication. Not only the presence of information, but especially how that information is organized, produces a positive or negative effect on our perceptive system (Klinger & Salingaros, 2000; Salingaros, 2006).

We assume an underlying genetic factor as the basis for why the ordered geometry of biological forms connects with and leads to healing effects on human beings. Many scientists now believe that evolution has a direction: the increasing complexity from emergent life forms in a primordial soup to human beings is not random (Conway-

Morris, 2003). While not speaking of "purpose", we may discern a flow of organization towards a very specific type of organized complexity (Carroll, 2001; Valentine, Collins & Meyer, 1994). As such, evolution becomes understandable in informational terms, where adaptive forces act in a fairly restricted direction (though without an end result in sight). Some species do reach a complexity plateau, and individual organismic components may simplify as a result of adaptation, yet the strand of human evolution has moved towards increasing complexity. A corollary to this conclusion is that all life forms share an informational kinship based on very special geometrical complexity, which builds up in a cumulative process. The built environment, considered as an externalization of intrinsic human complexity fits better in the larger scheme of things whenever it follows the same informational template. The design of our buildings and cities should therefore try and adapt to the evolutionary direction of biological life in the universe.

3. Biophilic architecture and neurological nourishment.

Human beings connect physiologically and psychologically to structures embodying organized complexity more strongly than to environments that are either too plain, or which present disorganized complexity (Salingaros, 2006). It follows that the built environment performs a crucial function — in some instances to the same degree — as does the natural environment. The connection process (outlined in the following sections) plays a key role in our lives, because it influences our health and mental wellbeing. Studying the geometrical characteristics of the type of visual complexity responsible for positive effects reveals its commonality with biological structures. Applying such concepts to architecture leads to two distinct conclusions. First, that we should bring as much of nature as we can into our everyday environments so as to experience it first-hand; and second, that we need to shape our built environment to incorporate those same geometrical qualities found in nature.

Human beings are biologically predisposed to require contact with natural forms. Following the arguments of Edward Wilson (1984), people are not capable of living a complete and healthy life detached from nature. By this, Wilson means that we benefit from direct contact with living biological forms, and not the poor substitute we see in so many urban and architectural settings today. Wilson's *Biophilia Hypothesis* asserts that we need contact with nature, and with the complex geometry of natural forms, just as much as we require nutrients and air for our metabolism (Kellert, 2005; Kellert & Wilson, 1993).

One aspect of biophilic architecture, therefore, is the intimate merging of artificial structures with natural structures. This could involve bringing nature into a building, using natural materials and surfaces, allowing natural light, and incorporating plants into the structure. It also means setting a building within a natural environment instead of simply erasing nature to erect the building (Kellert, 2005). While many architects may indeed claim to practice in this way, they more frequently replace nature by a very poor image of nature: an artificial representation or substitute that lacks the requisite complexity. That is in keeping with the abstract conception of architecture that has been applied throughout the twentieth century, and which continues today. Strips of lawn and a few interior potted plants do not represent anything but an abstraction of nature; not the

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real thing. This is a minimalist image lacking complexity and hierarchy. Biophilia demands a vastly more intense connection with plant and animal life, leading to the support of ecosystems and native plant species whenever possible.

Some good solutions incorporate small ecosystems consisting of a rich combination of plants within a building, or in a building's garden or courtyard. A flat lawn, by contrast, while better than a rectangular concrete slab, represents the same visual purity (emptiness) as the plain slab. Our senses perceive it as a single scale and are unable to connect to it fractally. Moreover, lawn is an ecological monoculture irrelevant to local ecology, because it exists on a single ecological scale. Nature exhibits ecological complexity: interacting plants that in turn provide visual complexity, which is a source of neurological nourishment. Not surprisingly, this way of thinking leads to buildings that are more sustainable, and which incorporate natural processes that help in energy efficiency. Sustainability goes hand-in-hand with a new respect for nature coming from biophilia (Kellert, 2005).

For all its benefits of helping users to connect with nature in their everyday interior work environment, this first approach is only a partial solution. The biophilic element here is plant life brought next to and into a building, but the building itself could still be made in an alien or artificial form and built using artificial materials. Human connection is then possible only with the plant forms, but never with the building itself. This problem is particularly acute in an age where the majority of architects use industrial materials and modernist typologies without question. This practice only serves to undermine the requisite natural connections that humans need. The natural aspect of an industrial building-plus-garden is simply a biological component grafted onto an armature that is fundamentally hostile to human sensibilities. There is always a sharp contrast between the building and the natural elements that it encloses. It still triggers an underlying neurological disconnection on a basic level.

A second, and much deeper aspect of biophilic architecture requires us to incorporate the essential geometrical qualities of nature into the building and urban structure. This implies a more complex built geometry, following the same complexity as natural forms themselves. Once again, there is a danger of misunderstanding this geometry and superficially copying shapes that are irrelevant to a particular building or city. Architectural magazines are full of images of organic-looking (and unrealizable) buildings; whereas we actually mean ordinary-looking buildings that are more adapted to human sensibilities. For example, making a giant copy of an organism out of industrial materials becomes an iconic statement that fails to provide any level of connectivity. The shape of a giant mollusk, crab, amoeba, or centipede is still an abstract concept imposed on a building; little better in quality of abstraction from a giant box or rectangular slab. That belies a fundamental misconception about living structure, which connects on the human levels of scale through organized details and hierarchical connections (Alexander, 2002-2005; Salingaros, 2005; 2006).

Neurological nourishment depends upon an engagement with information and its organization. This connective mechanism acts on all geometrical levels, from the microscopic, through increasing physical scales up to the size of the city. The correct connective rules were rediscovered repeatedly by traditional societies, and are applied throughout historic and vernacular architectures. Traditional ornamentation, color,

articulated surfaces, and the shape of interior space helped to achieve informational connectivity. Long misinterpreted as a copy of natural forms, ornamentation in its deepest expressions is far more than that: it is a distillation of geometrical connective rules that trigger our neurophysiology directly. These qualities are emphatically not present in the dominant architectural ideology of the twentieth century.

Some biophilic architects consider that neurological nourishment comes strictly from living biological forms. In their view, ornamented forms and surfaces are derivative of natural forms, and thus provide only a second-hand (i.e. vicarious) experience. We, on the other hand, believe that the underlying geometrical complexity of living structure is what nourishes humans. This geometry could be equally expressed in biological organisms as in artifacts and buildings: the difference is merely one of degree (Alexander, 2002-2005). If implemented correctly, it is not neurologically discernable, only more or less intense. Every living being incorporates this essential geometry to an astonishing degree (in its physical form), whereas only the greatest of human creations even come close. In this view, the distinction between the living and the artificial is left intentionally vague, and life itself is drawn closer to geometry. At the same time, this approach helps to explain the intense connection people feel with certain inanimate objects, i.e. the artifacts and creations of our human past.

Traditional techniques for creating neurologically-nourishing structures are wedded to spiritual explanations, which are often unacceptable to contemporary architects (and to business clients). Not surprisingly, the most intense connection is achieved in historic sacred sites, buildings, and artifacts. It is only in recent times that a scientific explanation has been given for what were originally religious/mystical practices of architecture and design (Alexander, 2002-2005; Salingaros, 2006). Today, it is finally possible to build an intensely connective building and justify it scientifically, by extending the geometrical logic of the natural world into the built world.

To summarize, two branches of contemporary biophilic architecture are beginning to be practiced today (Kellert, 2005). One basically continues to use industrial typologies but incorporates plants and natural features in a nontrivial manner; while the other alters the building materials, surfaces, and geometry themselves so that they connect neurologically to the user. This second type ties in more deeply to older, traditional, sacred, and vernacular architectures. So far, the first (high-tech) method has an advantage over the second (mathematical/sacred) method, because it is already in line with the industrial building/economic engine of our global society. Visually and philosophically very distinct, nevertheless, these two movements are contributing to a rediscovery of our immediate connection to the environment.

Perhaps the greatest impact of the biophilic movement is to establish a value system for a particular group of essential geometric qualities. Living forms and the geometrical characteristics they embody must be protected from destruction, because they provide us with neurological nourishment (Wilson, 1984). This is the seed for conservation, both of biological species, as well as for historic and traditional architectures.

4. An architecture that arises from human nature.

The desire to overcome nature, to separate man from the universe by placing him above natural constraints, led to the ultimate architectural assertion of the twentieth century, one expressing total autonomy. Adaptive processes were replaced by a formalized, self-referential, autonomous architectural order. The degree of separation that architecture placed between itself and nature was celebrated as a great accomplishment. This architectural movement culminated in the 1970s with the declaration made about an exhibition of current design work: "*This spectacularly beautiful work, elegant, formal, and totally detached from the world around it, represents a kind of counterrevolution in today's educational thought and practice.*" (Huxtable, 1999). Indeed, the value of twentieth-century architecture was now solely predicated on its degree of separation from the world around it: the world in which humans seek comfort and shelter (Masden, 2006).

To consider the service of architecture as something other than human seems contradictory to its very inception, for it was human nature that first gave it form by compelling humans to build. If we are to consider whom architecture should serve, and re-establish the relationship between architecture and humanity, then we must consider the essence of human nature, and grasp how human beings came to create particular kinds of structures. We must account for the neurological processes that operate as our interface with the physical world, and ask why, if these processes are intrinsically human, were we ever able to stray so far away from this human dimension.

Edward Wilson's seminal book *On Human Nature* (Wilson, 1978) laid the groundwork for understanding our biological nature, explaining how our actions are determined to a large part by genetic structure and evolution. Wilson thus places human actions on a sound biological foundation. Even so, people often contradict their biological nature by acting against it without any apparent logic, as when they join a mass movement (Hoffer, 1951). People are sometimes manipulated into adopting an ideology, which then controls their actions in violation of their biological nature (Salingaros, 2004).

These ideas are relevant to architecture in a positive sense. The early stages of the artistic process are a result of a vast number of unconscious forces and impulses. To initiate this process towards a healthier architecture, we need to ask: what are the tactile, perceptual, and mental processes necessary for a human sense of wellbeing? We are not going to describe how to incorporate biological elements into the built environment — the principal component of biophilic design — since that is dealt with by other authors (Kellert, 2005). Rather, we have developed techniques for design and construction that use materials to create a source of neurological nourishment. We draw from comprehensive architectural design methods developed only recently (Alexander, 2002-2005; Salingaros, 2005; 2006; Salingaros & Masden, 2007).

Several suggestions can help to implement this program. Appendix I to this Chapter summarizes some of the underlying principles that we and others are utilizing to design and build new enriching and engaging environments. Although built today with the latest technological materials, these environments reproduce with great effect the best that older built environments were able to offer. We, working today, and historical architects working in centuries past, strived for the same neurological nourishment from what we build. In the past, techniques for achieving this goal were learned intuitively. Modern science is revealing the mechanisms whereby neurological nourishment acts, so that we can learn to use it in a more controlled manner. Today, we are once again aware of the

physical properties and natural geometries that architects working in centuries past called upon to create the great human places we now wish to emulate.

Biophilic design's principal contribution makes use of plants and complex natural settings as much — and as intimately — as possible in the built environment (Kellert, 2005). While our design approach does not focus specifically on the biophilic component, it supports it in a fundamental manner. By re-orienting design away from formal or ideological statements, and towards a process of optimizing neurological engagement, we are setting up the conditions for accepting biophilia. Otherwise, the conceptual distance between non-responsive architecture and the natural environment is so vast that most people simply cannot bridge the gap. We are presently living in an alternative mental universe where human creations are forever distanced from natural forms. This gap is spreading daily, as the progressive development of new technologies rewards us with useful gadgets that are increasingly "unnatural".

To implement biophilic design, we need to create a conceptual framework based upon informational connection. This program goes against the current trends of academic specialization, since it requires the cooperation of many different disciplines. Present ways of thinking about architecture are inadequate: the representation of architectural problems has to change from an abstract domain to the natural domain dominated by human physiology and positive emotions. The forces pushing for a re-orientation necessarily come from outside architecture, and may even be resisted by architectural academia. If we are successful in this, then future architects will conceive architecture in a fundamentally different manner.

5. Three different conceptions of being human.

Biophilic design techniques depend upon the mental processes and physical mechanisms that people have evolved in response to the natural environment (Kellert, 2005). It is now necessary to consider the nature of human beings, which underpins biophilic design as a necessity and not an option. Many readers could misinterpret the biophilic focus on nature as diverting attention away from human beings themselves, even though its goal is to enhance human life on earth. This discussion is needed to prevent our work (and our colleagues' work) from being branded as just another architectural "style" that can be applied or ignored depending on the prevailing fashion.

We classify three fundamentally different conceptions of human nature, summarizing each of these levels in turn. In the first level, a human being is regarded as a component placed into an abstract, mechanical world. Here, human beings interact only minimally (superficially) with the natural world, a condition of being disconnected. This is an abstract conception of humanity, yet is representative of much of contemporary thinking. It is the world of the contemporary architect, in which humans participate only as sketches, intentionally blurry photos, or indistinct shadows on a computer screen. The imageability of the design is primary, with the occupant either absent or represented only symbolically. A human here is not even biological: he/she exists as an inert passenger in a fundamentally sterile and non-interactive world.

In the second level, a human being is an organism made of sensors that interact with its

environment. Here, humans are biological entities: animals that possess a sensory apparatus enabling them to receive and use measurable input. This is a condition of biological connectedness to the world, i.e. *situatedness* (Salingaros & Masden, 2006a). In this richly biological view, a human being represents a biological system that has evolved to perceive and react with inanimate matter and especially with other organisms. Humans are considered as animals (not meant in any negative way), sharing all the evolved neural apparatus necessary to make sense of the natural world. Human modes of interaction are those we understand through nerves and sensors.

In the third level, a human being is something much more than a biological neural system. The third conception corresponds to the much older metaphysical picture of humans as spiritual beings, connected to the universe in ways that other animals are not. This is a condition of transcendental engagement with the world. The definition of human essence extends into realms more properly covered by humanistic philosophy and religion. Much of what it means to "be human" lies in this domain, and these additional qualities distinguish us from other animals. To dismiss all of this as "unscientific" would be to miss the point of humanity. In the pre-scientific ages — as for example, the Middle Ages in Europe — our conception of what we were as human beings was almost exclusively based upon insight that came from internal development. Transcendental engagement anchored our sense of *self*, and continues to do so for the majority of people in the developing world today. Mystical and religious, this intuitive understanding serves to tie human beings to their world in a manner independent of science. The connection, moreover, is believed to have been much stronger than the later development of a strictly scientific framework linking human beings to the rational dimension of the physical universe.

Curiously, the three levels of being human, going from detachment (disconnected), to a biological connection (situatedness), and finally to a more profound transcendental engagement, correspond to going backwards in historical time as it pertains to human existence. This seems counter-intuitive at best. If one were to reword this observation, it could be said that humankind has regressed in the depth of its connection to its surroundings (i.e. the universe) over the past decades and centuries. Just because we increased our scientific knowledge of the world, this does not guarantee that we maintain our connection to it in the human dimension. Indeed, the Cartesian method required us to detach ourselves from our world in the name of scientific enquiry, in order to be able to perform unbiased experiments. This may be fine for scientific experimentation, but it is certainly no way to maintain our human nature and to effectively operate within the world as human beings.

6. Level one: the abstract human being.

The "modern" human being inhabits an industrialized, technological world. Since this world has become an ever vaster and encompassing machine, so too its human inhabitant has become but an ever smaller (and, by implication, less significant) component of that machine. The biological constitution of these contemporary human beings has little relevance to their situatedness in the universe: such a person could just as well be made out of metal, wires, and a minimal number of electronic sensors — a robot. The

biological (not to mention the transcendental) nature of humanity is herein denied. A human being is simply a neutral cog in the machinery of the universe. It doesn't help that contemporary physics paints precisely such a hopeless picture of cosmic irrelevance for human nature and the human spirit.

In contemporary architecture, reluctant acknowledgment is sometimes made to the genetic structure of a human being, but it is far less than would at first appear. Too often, even the most rudimentary neural capacity of humans does not enter into play when designing buildings and urban environments. Human physiological and psychological response seldom figures in design discussions today. Architects pretend to have surpassed human nature. Instead, certain formal and abstract notions about space, materials, and form are of primary concern. Those do not arise, however, from a full understanding of the processes at work that give human beings their existential foothold on earth.

A movement to mold human beings into manipulable consumers of industrial products has been taking place for many decades. Much broader in scope than architecture and urbanism, these two disciplines have nevertheless played a significant role in an era of massive social engineering. In the drive to transform human beings into controllable objects, people's connection to nature are suppressed. Modern individuals — at least in the more developed countries — live in a physical world defined by machines and industrial materials, and whose information fields come from media images and messages. Nature is either eliminated from the human environment, or has been relegated to a purely decorative role. Evolutionary developed sensibilities have been numbed. The world's remaining population is no better off, because it aspires to emulate this unnatural state as a sign of progress. An automated, disconnected population is insensitive to the healing effects of natural environments.

A more benign, but nevertheless equally effective transformation led to the abstraction/mechanization of the human environment. Early 20th-Century advances in microbiology and sanitary practices coincided with the introduction of industrial materials. A "healthy" environment became associated with a visually sterile, industrial "look" of polished metal or porcelain surfaces. For example, kitchens changed from being geometrically messy to looking like sterile factory environments; and from being made from soft and natural materials to being built using hard industrial materials (Salingaros, 2006). Plants (not to mention domestic animals) had no place there. People's preoccupation with improved health made them suspicious of all life, not just the harmful microbes and fungi that cause disease. This was a great misunderstanding, since microbes can thrive on any surface, even ones that look sterile to the naked eye. But the clean, industrial "look" became part of our worldview, and we are still threatened by signs of life that violate it.

This contemporary condition demonstrates that human beings can be psychologically conditioned to act against their biological nature (Hoffer, 1951; Salingaros, 2004). We are now facing a population whose sensibilities have been detached from most other life forms, and oriented principally towards an artificial world of images and machines. Explaining the benefits of biophilic design to such individuals — who no longer see relevance in real trees, animals, and ecosystems — presents a serious challenge.

7. Level two: the biological human being.

We are biological creatures made of sensors that enable us to interact with our surroundings. Intelligence and consciousness are evolutionary products of our sensory systems. Up to a certain point (more than we care to admit), we share this neurological basis with other creatures of the earth (Wilson, 1978; 1984). In the past, an innate understanding of how forms, spaces, and surfaces affect us was used to design the built environment, aiming to maximize its positive effect on us. That changed when formal criteria and abstractions were introduced, replacing those of an older, humanistic architecture. By coincidence, societal discontinuities leading into the twentieth century made this replacement possible, a change which could not have taken place before then (Salingaros, 2006).

However, this does not mean that our sensory apparatus has changed in any way. We still have the same genetic structure, and our physical and psychological needs have remained the same over many millennia (Wilson, 1978; 1984). Our neurophysiologic requirements have been tempered to some extent by fashionable ideas, images, and ideologies, yet our response mechanisms still operate automatically. Therefore, we will instinctively react in a negative manner to a built environment that is neurologically non-nourishing, or which might actually cause physical anxiety and distress. It is very easy to understand the type of environment that is healthy for us — or, conversely, is unhealthy — based upon our sensory apparatus. We need only to pay heed to the signals from our own body, unencumbered by psychological conditioning.

Empirical evidence continues to accumulate towards a greater understanding of how humans operate physiologically in the built environment (Frumkin, 2001). In hospital design, the geometry of the environment plays a significant role in how long it takes for a patient to be cured. Roger Ulrich has done pioneering work in this topic (Ulrich, 1984; 2000). Surprisingly, schools do not show a strong enough interest in human physiological and psychological response to the built environment, despite decades of experimental findings on this topic. Architects instead seek greater distance and obscurity in the ethereal terrain of contemporary philosophies (Salingaros, 2004). Departments of Architecture around the world still train students in Hospital Design based on formal, stylistic ideas of spaces and materials, not paying attention to Ulrich's work.

Our eye/brain system has evolved to perceive fine detail, contrast, symmetries, color, and connections. Symmetry, visual connections, ornament, and fine detail are necessary on buildings; not for any stylistic reason, but because our perception is built to engage with those features (Enquist & Arak, 1994; Salingaros, 2003; 2006). The physiological basis for sensory experience is the ultimate source of our being, which thus relies strongly on certain geometric elements to which we connect. Creating an environment that deliberately eschews these elements (visual elements which are found in nature and in all traditional architectures) has negative consequences for our physiology, and thus for our mental health and sense of wellbeing (Joye, 2006; 2007a; 2007b; Kellert, 2005).

Environments devoid of neurologically-nourishing information mimic signs of human pathology. For example, colorless, drab, minimalist surfaces and spaces reproduce clinical symptoms of macular degeneration, stroke, cerebral achromatopsia, and visual agnosia (Salingaros, 2003; 2006). We feel anxious in such environments, because they

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provoke in us a similar sensation as sensory deprivation and neurophysiologic breakdown. It is curious that architectural design in the past several decades incorporated more and more such alarming elements and devices as part of its stylistic vocabulary. Some architectural critics attempt to portray those in a positive light using seductive images, and defend them by employing specious references to technological progress (Salingaros, 2004).

The discipline of Environmental Psychology actually began in faculties of architecture, as a natural investigation of how built environments were affecting people. As soon as the first results (several decades ago) indicated that some of the most fashionable contemporary architectural and urban typologies, spaces, and surfaces might in fact be generating physiological and psychological anxiety in their users, fellow architects lost interest. Environmental Psychologists moved (or were systematically relocated) outside architectural academia, into Departments of Psychology, which is where they can be found today.

Ironically, to understand the environmental aspect better, we turn to studies on higher mammals. Judith Heerwagen has studied zoo animal behavior in naturalistic versus more artificial environments (Heerwagen, 2005). Starting from substantial observations of zoo animals, she reports the results of implementing a transformation towards more naturalistic habitats. As a consequence, the animals' psychological and social well-being has been drastically improved. Zoo animals kept in drab, monotonous, and minimalist environments (i.e. those that we humans also perceive as boring and depressing) exhibited neurotic, aberrant, and antisocial behavior never observed in the wild. Moved to more naturalistic and stimulating habitats, the animals returned to more normal, healthier behavior patterns.

This body of results has dramatic implication for our children. Evidence has been accumulating since the 1960s that complexity and stimulation in the environment can lead to increased intelligence of a developing animal. Incontrovertible results are obtained with young rats raised in information-rich environments, whose brains increase in size, and can improve their neural connectivity by up to 20% (Squire & Kandel, 1999: page 200). This represents much more than just an anatomical change in the brain, because it optimizes the cortical physiology responsible for intelligence. Those rats raised in enriched environments are then observed to do much better in intelligence tests (such as solving complex maze problems) and training. We interpret this result as the fulfillment of a necessary external component in the brain's development. It also raises questions of collective culpability for neglecting or minimizing neurological connective structure.

We need to point out the importance of relying on clinical studies rather than on surveys. Many studies recording user preferences have been done over decades, some of them uncovering the advantages of natural environments, and of environments mimicking those geometrical qualities (Joye, 2006; 2007a; 2007b; Kellert, 2005; Kellert & Wilson, 1993). Nevertheless, a large number of those studies showed only moderate preferences, or were inconclusive. A recent experiment raises the possibility that those earlier results may in fact reflect conditioned response. In a clinical comparison of two distinct environments, one a plain room, and the other with wooden beams added to create hierarchical scaling, the subjects did not express any preference. Yet the

physiological monitors recorded a marked response in favor of the room with hierarchical subdivisions and natural detail (Tsunetsugu, Miyazaki & Sato, 2005). We (and the study's authors) conclude that physiological effects of the environment cannot always be consciously recognized.

8. Extending level two: expert knowledge and patterns.

A major question in cognitive neuroscience is: which components of the brain's wiring are innate (genetic), and which components are acquired through interaction with the environment (learned)? There is a dimension of being human that goes further than direct sensory perception, yet remains within biology. It is simply sensory experience on a higher hierarchical level. That mechanism is a product of learning, and is vital in being able to distinguish human beings from machines. It is also of crucial importance to the arguments raised here about architectural connection to the *self*. Human existence, and the projection of the *self* into the world, is formulated from within the individual through perception of the outside world, thus generating an interpretative framework.

This is the domain of "expert knowledge", where complex data about the environment have become so internalized that perception seems almost extrasensory (but is not). Experience represents a sensory response that has become too complex for us to easily describe, categorize, or understand in an analytic manner. Experience provides us with a repertoire of patterns, which we then use to unconsciously match unfamiliar situations (Klein, 1998). Many qualities often attributed to intelligence are in fact the result of well-developed perceptual skills at the level of expert knowledge.

Our basic neurophysiologic make-up is genetically determined. After birth, however, our neural network is shaped by the environment and learning, thus acquiring additional, non-genetic properties. These properties include the recognition of structural and functional patterns. The genetic basis makes learning structures possible, but privileges a certain type of learning structure that is based upon the genetic template. Learning, in turn, helps propagate our genes, thus these two informational components are interdependent. Altogether, the genetic and learned components of our memory and sensory systems work as one seamless whole, acting as a set of innate responses.

Emotional learning is the result of sensory input, but remains subconscious (i.e. stored in nondeclarative memory). It works independently of conscious (declarative) memory, since much of the information that we process is not accessible to conscious awareness (Squire & Kandel, 1999). Patterns learned emotionally through perception act in the same way as inherited (genetically-based) responses. The reason they evoke a positive emotion to begin with, is because they satisfy an internal template. As a result of our evolution, our internal template is very specific. Many aspects of our behavior and personality are either acquired in this manner, or are innate, and both are stored as unconscious knowledge (Squire & Kandel, 1999: page 173).

Andrius Kulikauskas (2006) makes the following perceptive statement about behavioral patterns, which have a biological origin:

"*Patterns also can help us make sense of the social importance of our body language, for (from videos taken by sociologists) it seems that we have a 'sixth sense' by which we*

literally dance in relationship to each other (shifting our body at speeds faster than we are aware) and which I imagine we cue against our environment (which is why ornamentation may be very important). This is a faculty that I believe autistic people do not have (as if they were blind or deaf in this regard) and so must focus their conscious mind on cues that most of us find simple to read (such as when are others interested or not in what we have to say)."

Patterns recognized by our neurophysiologic apparatus are a key to understanding humanity and its connection to the universe. Patterns organize individual actions into more complex wholes. While this is a process well understood in a language, where words are combined to achieve a meaningful message, it remains outside most people's analytical understanding of the world. Cognitive psychologists recognize patterns as schemata that identify certain preferred sensory inputs. Patterns also control coordinated body movements. Almost every human activity will be found to contain patterns, and those patterns generate the forms and connective complexity of traditional architecture and urbanism (Alexander *et. al.*, 1977). We will discuss later how humans connect to particular robots and computers that mimic human patterns of speech or behavior.

Expert knowledge in architecture and urbanism is embedded in traditional environments. Whereas some design components are contextual (i.e. cultural, temporal, or location-specific), many are indeed universal. All we need to do is to "read" them from the UNSELFCONSCIOUS BUILT ENVIRONMENT. Christopher Alexander's *Pattern Language* codified evolved patterns of how humans interact with their environment and with each other (Alexander *et. al.*, 1977). This prescient book established a practical combinatoric framework for design, based on evolved solutions. Incidentally, it already contains many of the key concepts that later came together to define biophilic design. Originally expected to generate a more human architecture, academic architects showed little interest in this information (Salingaros, 2005; 2006). Instead, the patterns framework was picked up by the Computer Software community, which now uses it routinely to handle the complexity found in large software programs.

In Appendix II of this Chapter, we have summarized several Alexandrine patterns. The reader can readily see how these design patterns anticipate and support biophilic design. Architects can draw upon the *Pattern Language* (Alexander *et. al.*, 1977), combining that helpful knowledge with the latest notions of human adaptivity into an innovative design method. In turn, the value of the pattern language can be truly appreciated only now, in the context of biophilic design.

When the *Pattern Language* was first published, the most important supporting results from evolutionary biology were not yet widely available. Today, we understand evolutionary convergence as a fundamental indicator of the parallel, independent evolution of specific patterns (Conway-Morris, 2003). Faced with a vast solution space, evolution has repeatedly found a relatively small number of working prototypes. Those are characterized by morphological similarity. They have been re-discovered by distinct genetic strains converging towards the same solution by exploring adaptive possibilities. In the same way, a small number of architectural and urban patterns combining social and geometrical elements have arisen spontaneously in different cultures and in different times. Their appearance is evolutionary, since they are the end result of typological exploration via trial-and-error over generations. Out of an uncountably infinite number of

possible typologies, the adaptive ones are relatively few, and can be classified. Obviously, there are rules (whose precise nature we ignore at present) operating at a high level of selection, so that design of the human habitat is far from random (Alexander, 2002-2005).

9. Further extending level two: human-machine and human-animal interactions.

In the effort to reconnect architecture to human sensibilities, it seems appropriate to learn from other fields where such connection is achieved. Any explanation of how natural environments influence human beings must uncover what exactly is being transmitted; and what effect that information has upon our physiology. It thus makes sense to study human-machine interactions, which rely on analogous mechanisms. Biophilia works through information fields, but how do human beings really connect to non-human systems? Can we tell whether a system we actually connect to is human or non-human? From within contemporary technologies of computers and the science of robotics, we can pick up clues about our own interactions on the level of being human.

Alan Turing (1950) devised the oldest test meant to distinguish a human being from inanimate information processors (i.e. computers). Its basic premise was that one should be able to determine if a respondent is a computer or a real person from the responses to questions in a conversation. The annual Loebner Prize awards the robot (or rather, its builder) that comes closest to acting human. Just in case, there is a large amount of cash on reserve for when the Turing Test will eventually be passed. Even so, we have the example of the notorious ELIZA program written by Joseph Weizenbaum in 1963, where a piece of software emulated a psychiatrist so accurately that many of its respondents were convinced there was a real person at the other end of the computer terminal (Weizenbaum, 1976). And things have progressed remarkably since those early times in computing.

In a separate development, Rodney Brooks builds mobile robots that can mimic many non-verbal human qualities (Brooks, 2002). Even though they make no attempt to physically resemble human beings in form, they are programmed to "engage" humans by means of behaviors such as eye and head movement (moving what we might identify as their "eye" and "head"). Those robots are able to express emotions through movement in ways that mimic human behavior, and are capable of doing so because Brooks has programmed varying facial expressions. They have an "aliveness" to them that is most unusual in inanimate objects. People respond involuntarily in a way that engages the robots, and seem disappointed or shocked when these robots occasionally act in a non-human manner (Brooks, 2002: page 149).

As the above examples make clear, it is possible to emulate human qualities and emotions, at least partially, by means of programs that mimic patterns of speech, movement, and behavior. The observer interacts through patterns of a very specific type of complexity that is characteristic of living, and specifically human, beings. We are describing complex connections established on an altogether higher level, beyond simple sensory input such as visual stimuli. Such patterns identify human qualities, even though it may only be a machine mimicking a human being.

Increasing the complexity of interaction in a definite direction (defined precisely by what our neurophysiology and sensory apparatus are built to detect) eventually leads to higher degrees of human connectivity. We may connect only partially to a robot exhibiting certain human responses, but we fully connect to a real human being. Human patterns come together and cooperate much better than computers or robots have been able to do so far. We interact with a close friend or family member on yet a different level, since we share extra layers of commonality. This goes even further than genetics. Acquaintance has given us knowledge and experience of that person's behavior that has become intuitive: expert knowledge of their thinking and behavioral patterns enables us to "read that person's mind".

A separate topic of relevance concerns human-animal interactions. Human beings co-evolved with the other animals, and domesticated some of them. Since the beginnings of history, people have benefited from (and documented) the positive emotional and health effects of contact with domestic animals. This is one of the dimensions of biophilia. In recent years, more rigorous evidence has been accumulating on the therapeutic effects of animal contact (Barker, 1999). There is a growing industry in animal-assisted therapy (Roth, 2000). While we don't wish to enter into this topic's scientific foundations here, we single out the connective channel as a key aspect to our own discussion. Whatever positive physiological and psychological effects are observed to result from human-animal interactions, they must certainly occur via information exchange. And such information is richly complex, and pattern-based.

The reason we are talking about animals, robots, and artificial intelligence is to establish the human need and capacity for information exchange. What makes us recognizably human is a set of complex, organized informational patterns that evolved along with our body. Our sensory apparatus instantly detects the degree of kinship of any perceived patterns to our own selves. The processes at work in our neurological hardware require a far greater degree of information than the abstract forms of architecture currently provide. Informational coding is missing from today's architecture. Within the intentional condition of contemporary architectural environments we are detached from the perceivable world.

10. Level three: the transcendent human being.

Exploring human nature more deeply leads us to understand humanity as something more than a mass of intelligent animals that reproduce licentiously, and thus destroy the natural world by exhausting all of its resources. In times past, humanity had a more noble conception of itself. An anthropocentric view, yes, but also one endowed with responsibility towards a natural world that was itself alive. This was a more authentically sustainable form of being. To advance our idea, we resurrect the old romantic worldview of a past in which people felt connected to the universe: in terms of religion, mythology, societal kinship, traditional values, etc. We are not trying to discount how far anthropology is based on genetics, only trying to recapture something lost.

Whatever one may say, there was a more profound conception of a human being's connection with the universe, and it was not based on theoretical presupposition (or science in the strictest sense). Curiously, the early development of modern science tended

to question, and therefore weaken our valuation of this connection. Our place in the universe was nevertheless based on empirical observation, which is coincidentally the basis of all science. People experienced a deep connection with each other, with living beings, and with nature. They experienced a wonder at the Creation (Wilson, 2006). This was as evident as data collected from an experiment, although the connection is not measurable on a quantitative scale. Traditional explanations for the connective process did not come from science, they came from inner beliefs. Expressed in terms of emotions, those truths could not survive the rise of science.

Our present understanding of biological and ecological interdependence is only very recent. Wilson has made remarkable progress in providing a biological basis for what was previously attributed to the supernatural aspects of human nature (Wilson, 1978; 1984). A real phenomenon such as our connection to the physical world, experienced beyond any reasonable doubt, is nevertheless vulnerable if its explanation is not grounded in science. This is one reason why the mechanism of neurological nourishment and engagement was dismissed at the beginning of modern (industrial) times. We are finally accumulating scientific evidence to support conclusions reached much earlier by traditional societies.

Christopher Alexander (2002-2005) raises the same issue about our loss of fundamental connectivity, in the context of architecture and urbanism. Alexander argues for an underlying and far-reaching interconnectedness based upon fundamental geometrical properties. He also shows how that has been severely, sometimes catastrophically damaged (Salingaros & Masden, 2006b). This work is starting to become better known with profound affect, as people realize that the twentieth century lost a major component of human connection to the universe. Steps towards disconnection were taken voluntarily, sometimes even eagerly, in the name of technological progress. Unfortunately, such traditional knowledge and beliefs as had sustained the built environment for millennia were readily discarded.

Much of what we take to be uniquely human, such as our emotions and higher aspirations, is a manifestation of our transcendental engagement. The emotion of love has throughout the ages generated a strong attachment to other individuals. The love of one's creator anchors our religions, and created the greatest buildings the world has known. Even though romantic love can be partially explained in biological terms (the search for compatible genes), that surely misses the essence of the experience. All the world's poetry, songs, music, and literature that have been generated by love cannot be explained away as the primal sexual urge of biological reproduction. And even those aspects that have a biological explanation are better described in their own domain: the connective dimension of human nature.

That also holds true for our place in the universe. We connect with our universe through the animating aspect of *self*, filtered through culture and religion. People's behavior, values, and concept of *self* are thought to be learned from their relationship to the world, through existence. It is existence that gives form to reality through human perception, whereas the body and mind simultaneously manufacture that which we know as reality. For many human beings today, and for the vast majority in earlier times, this connection was deep and profound. In intensity and meaning, it goes far beyond (in terms of complexity) what our direct physiological sensors are programmed to reveal (Masden, 2005; Salingaros & Masden, 2006a; 2007).

The theological concept of "mystery" is relevant here: as something that is sensed to be both true and internally rational, except that its totality cannot be fully grasped (McGrath, 2005). In this sense, mystery is not irrational, but inevitable. Both biophilia and architecture have components that belong to this category, and to dismiss them would be to impoverish our conception of those disciplines. The scientist's interpretation is to be cautiously optimistic that with improved experimental techniques, effects that the natural environment is observed to have on human beings will be more completely explained in due time. The non-scientist may be content to consider the possibility that not all of the universe's mysteries are open to human comprehension. Either way, we should not ignore observed effects just because we don't understand the mechanism by which they act. Arrogance (or fear) ignores observations when they threaten an established, but narrow, conception of the world.

People's attachment to their universe, and to their beliefs, is as deep as their attachment to life itself. In traditional pre-industrialized cultures, the awe and fascination with natural forms and with Deities is indivisible. Nevertheless, history is a sequence of human mass activity, sometimes violent as in uprisings and wars that are driven by beliefs in how the world should be structured and connected. People are willing to sacrifice their lives in order to achieve a certain type of connection to their mental world, to impose a particular structuring for those left behind, or to prevent what they perceive to be a disconnection (a detachment from their picture of the world). Ironically, they will readily detach themselves from the real world in order to follow an abstract ideology (Hoffer, 1951; Salingaros, 2004). Rational thinking in a technological age did not save humanity from such aberrations; and certainly has not preserved our deeper connection to nature.

11. Architecture that transcends materiality.

On many levels, what it essentially means to be human is lost in the practice of architecture today. The denial of human nature acquired greater authority at the turn of the twentieth century, coinciding with the rise in scientific and technological applications. A likely explanation is that people became infatuated with early scientific advances, which confused technology with science itself. They misinterpreted crude technological applications as a substitute for a more complex reality. The promise of science — but a promise based on false premises, eagerly followed by people who did not understand science — has over time stripped humanity of some of its most important non-measurable qualities. What could not be quantitatively measured was presumed not to exist, and was relegated to superstition; a vestige of the past that merited only contempt.

Architects throughout the world — those teaching in universities or working in professional offices to produce commercial buildings, modest apartments, and private houses — thirst for some signs of truth in their profession. They dream of a new architecture they can use to overcome the limits of what they are doing, and to broaden their horizons with infinite newfound possibilities. New forms, new ideas, and new concepts — that's what keeps architecture perpetually moving forward, and keeps architects emotionally alive. Newness, moreover, is most invigorating when it can be applied to one's everyday practice. Accepting every architect's thirst for truth, biophilic

design offers a more genuine and healthier alternative to what architects currently embrace.

The manifestation of life transcends both material and spiritual realms of thought. Living structure is animated in a mysterious manner. Traditional categories such as physical/spiritual and inert/alive become somewhat blurred, as inexplicable phenomena occur to make things alive. We now understand life as a state of matter possessing certain very special chemical/organizational properties, and are discovering more and more of those properties in the laboratory. We may know many of their details, but cannot be entirely sure we comprehend how they all work together. It helps to discuss these matters in a culture where science and religion are not kept strictly separate, because religion served most effectively to keep alive a sense of wonder at living forms.

Christopher Alexander has investigated these fundamental questions (Alexander, 2002-2005). Alexander's results reveal how living structure may be conceived as crossing over between animate and inanimate forms. Physical matter does transcend its inert materiality through very special informational configurations. This process can endow physical forms with the characteristics of life: certainly not all of them (i.e., not including metabolism and replication), but moving in a direction towards structures that we identify with living forms. Parallel with this solidly geometrical process, the closer we approach our goal of creating "life", the closer we seem to be moving towards traditional extra-scientific ways of interpreting the world.

Human beings feel most alive in their spiritual moments. In such instances, we feel connected to our environment, in a deep sense belonging to it and to the universe. This stage of inseparable reality has been described in spiritual terms. The experience is unmistakable. It enables us to inhabit the material and spiritual worlds at the same time. The impression of material transcendence is connected with the sacred. Religious architecture of the past helps us to achieve this type of connective experience; indeed, that was its original purpose. The only problem is that traditional explanations of what is going on tend to be non-scientific. Alexander's life work provides a scientific foundation for this observed phenomenon. His results raise many questions about the nature of reality (Alexander, 2002-2005; Salingaros & Masden, 2006b).

As far as architecture is concerned, we accept the highest level of connectivity of human beings to the material world as real. When this occurs, the built environment may be said to transcend its materiality. All traditional cultures have built sacred spaces in which one experiences an unusually high degree of connection. Sacred spaces are nourishing to whoever occupies them. How is this achieved? We believe that it's the same process that underlies the biophilic phenomenon. Rather than any mysterious force field unknown to physics, informational fields act to establish a manifestation of the requisite connections. Those who love nature can experience a transcendent communion with it. Ancient religions explain this mystery as sacred communion with nature. Consciously working with the mechanism of informational exchange, we can re-create buildings having the same intense degree of connection. Such buildings will provide the highest level of neurological nourishment.

Hassan Fathy grew increasingly to interpret architectural and urban form in sacred terms. He was not referring to religious buildings, but to everyday dwellings for the poor,

a project that occupied him throughout his entire life (Fathy, 1973). Fathy saw in simple built spaces, surfaces, textures, and configurations an expression of the sacred. This unfortunately brought him into conflict with post-war industrialization, which his colleagues adopted as the only rational solution to the world's housing problems (Pyla, 2007). Many other architects, including Louis Sullivan and Frank Lloyd Wright, were likely to talk in mystical terms about their architecture, trying to express something they felt instinctively — and could build — but could not formulate very clearly. Our explanation of how architecture connects to human beings therefore rests on considerable precedent, and can now be more clearly understood in neurological terms.

We are aware, however, of a tremendous existing confusion on how to actually achieve architectural transcendence. This is most evident in contemporary religious architecture. According to their architects, some new churches built in a stripped, minimalist style are supposed to represent transcendence. They do nothing of the sort. Without natural elements, figurative art, or ornament, they fail to engage the user in any positive way. Their empty informational field only communicates sensory deprivation, provoking physiological unease. Far from working on the transcendent level of human existence, this design style is a throwback to the mechanical conception of humans. We see a form imposed on top of this presumption ignoring human connective needs. Despite any probable good intentions, the result amounts to a triumph of the architect's will over human nature.

Coming around in a reinforcing circle of reasoning, the effort to create "life" in architecture teaches us a new and welcome humility. Once we focus our efforts on technically establishing neurological nourishment, we cannot fail to notice that nature achieves this effortlessly. Nature also does it so much better than we could ever hope to do. A single live flower can humble most structures built by humans. Interpreted correctly, this calls for a drastic re-orientation, not only in how we build, but also in our basic value system. We should simply put to use what nature already provides for our neurological connectivity and nourishment. Plants, animals, and ecosystems thus assume a priority over our own constructions. This is the essence of biophilia.

Possibly, our fellow biophilic designers might feel that we have crossed too far into philosophy/religion in trying to support an innovative design method. We insist, however, that we are merely following the thread of thought to its inevitable and logical conclusion. Both Christopher Alexander (2002-2005) and Edward Wilson (2006) have been led independently, at the summit of their careers, to re-consider the meaning of life and human existence. We (and they) see the future as viable only if humankind re-attaches to biological life and to the life-generating geometry of the universe. For this reason, Alexander and Wilson have called for a rapprochement between science and religion (proposing two very different types of alliance) in order to save the Creation.

Architecture, as an activity to house human beings, acquires deeper meaning in the world depending upon the human vision of the nature of God. Does God exist in an abstract, minimalist geometry? Or is God instead to be found where there is also evidence of life? In the latter view, which is supported by the world's main religions, God is manifest in a natural geometry — in living structure (Alexander, 2002-2005). God is more likely to reside in the highly-organized complex geometry of the fundamental structure of matter. But these two types of architectural geometry (minimalist and

biophilic) are opposite in their mathematical qualities. There exists a basic incompatibility between two opposite geometries preferred by human beings. A deep theological question, we must nevertheless raise it here because it leads to a separate philosophical validation of biophilia.

12. Conclusion.

Human beings have evolved the ability and the need to process information embedded in their environment. Architects, on the other hand, in the process of distancing their work from what is natural, have come to rely increasingly on artificial criteria and the superficial manipulation of images. When images and surface effects supplant everyday human desires and sensibilities in the name of artistic endeavor, humans are left to live out their lives in a series of ill-fitting, over-exaggerated, and often idiosyncratic formal architectural schemes. Ordinary people see this trend — architecture turning away from human qualities — as the imposition of building design against their most basic instincts. But they have been able to do little about it, given the nature of the business of architecture and the seduction of technological progress.

There is a neurological and physiological necessity to engage the environment. Architects today can accomplish this by recognizing the operations that connect humans with their environment, and by distinguishing among distinct levels of being human. Biophilic design re-orients architecture towards a world governed by coherent information; it also leads people to think on many levels of complexity (which is the way nature works). Reinforcing this tendency, architects can now adopt a higher standard: one which asserts that buildings are by their very nature human. Students, academicians, and practitioners of architecture wishing to contribute to environmental regeneration must therefore ascribe to the essential qualities of human nature, i.e. the physical and mental processes that allow us to occupy our world.

The information necessary for humans to connect to the world around them can take many forms, including calligraphy, representational ornament, and abstract geometrical ornament; with the physical object increasing in size from an architectural detail up to architectural structures and urban spaces. In a fundamental sense, therefore, the natural and traditional built environments rich in informational content make a place more intrinsically human. The natural world interfaces smoothly with human creations, but only when those are built in the same coherent manner. By emphasizing informational content, we can shape the built environment according to the constituent logic and order necessary to provide neurological connection at a human scale and thus emotional nourishment.

APPENDIX I: Fourteen steps towards a more responsive design.

The following are some practical techniques that can be used to implement a more responsive and natural approach to design. They form part of a recently-developed comprehensive method for architectural design (Alexander, 2002-2005; Salingaros, 2005; 2006; Salingaros & Masden, 2006a; 2007). We emphasize that these points do not simply represent our personal preferences, nor do they include all the supporting rationale that

leads up to them. They are the outcome of a theoretical and scientific methodology that is too voluminous to be reviewed here. These design steps support biophilic design. The logic is clear in that they do not *arise* from the biophilia hypothesis, but instead *support* it from independent directions.

We could publish these points separately as a design method meant for practicing architects. They might be accepted, or not, based upon the novelty of the "look and feel" of the resulting buildings. This is the manner in which today's architects adopt new styles, and initiate new movements in design. Certainly, the sensory quality of the type of buildings we propose is strikingly different from the crystalline, blob-like, jagged, or minimalist environment produced by some contemporary designers. Nevertheless, some architects may resist the implementation of a so-called "biophilic style", precisely because it serves to displace their preferred style. This may spark a heated polemic driven by ideology, politics, and idiosyncratic preferences. To prevent the debate from getting stuck in such an unproductive direction, the body of this Chapter is necessary, because it presents an architecture devoid of stylistic predilections.

(1) The smallest perceivable scale is established with either the microstructure of natural materials, or by using very fine-grained texture/ornament. The ordered complexity of natural structure cannot easily be duplicated on this scale. The region containing fine detail has to be immediately accessible to human contact (and not lost at a distance). A universal rule for the distribution of sizes in a complex system suggests that there should be very many identifiable components on the smaller scales, several on the intermediate scales, and only a few on the largest scales. The smaller the scale, the larger is the number of elements contributing to that scale. Fractals obey such an "inverse-power-law" distribution. This rule implies an enormous amount of necessary ordered detail on the smallest scales, just as seen in nature. It also implies the necessity for articulated texture and ornament: not on every surface, but prominent and accessible nevertheless.

(2) Design that adapts to human sensibilities should have a very definite scaling hierarchy. Obvious differentiated subdivisions or components need to obey a scaling rule, where elements on the next larger scale are roughly 3 times (more accurately, 2.7 times) larger than those on the immediately smaller scale. Although the dimension of each scale can be very approximate so that the ratio between successive scales could be anywhere from 2 to 5, no scale should be missing. This is essential. A very different concern is to avoid scales intermediate to the scaling hierarchy, since those would distort the ratios. All fractals have a precisely-defined scaling hierarchy (each with its own scaling ratio). Despite the widespread use of natural materials such as wood and grained stone, however, the intermediate and larger scales have not been designed coherently in recent decades, so the fractal connective effect (which emerges only with the proper scaling hierarchy) is lost.

(3) Symmetry is essential in design, not as expressed by an overall scale, but rather by the richness of subsymmetries on smaller and intermediate scales. Connective symmetry is an extensive quality, ideally acting throughout all levels of a scaling hierarchy. The density of subsymmetries, and their intensity of interaction inside a particular scale and

across distinct scales, is what leads to visual coherence. Many of those symmetries are going to be approximate, and a non-modular use of materials accommodates such broken symmetries. Here we apply results on symmetry breaking, where small individual variations in a module contribute to create an informational higher scale when modules are combined. This emergent phenomenon is impossible to achieve with repeated identical components or modules.

(4) Small-scale construction systems should be inverted — conceptually turned inside out — to optimize informational load. Nowadays, wooden studs and beams are built inside walls and covered with industrial sheetrock (plasterboard). This type of construction hides the materials with the greatest informational content, presenting instead an abstracted geometry to which we cannot connect. Innovative architects can and should develop new structural systems, which preserve natural materials for the visible surfaces, to be used in regions that human beings can directly access through sense or touch. This being said, however, care should also be taken in how those materials are placed within the structure. Despite Frank Lloyd Wright's habit of using rough stone and brick for interiors, which at some level do provide a more intense informational experience, their surface is hostile to the touch, thus they should be located out of immediate reach. We also don't imply cutting all wood into sheets of veneer: the standard 2x6 inch boards could still be used to bear loads, but in such a manner or configuration so as not to hide their natural grain and soft acoustical properties. Load-bearing wall interiors such as concrete or steel (with non-connective surfaces and textures) can replace the current misuse of more natural materials such as wood.

(5) Large-scale construction requires different techniques altogether. But we have to be smarter about how we use industrial methods for larger buildings, since there is no connective value in an "industrial look". We can learn a lot from 19th-Century modular production of ornamental panels and building components. Going back to the precedent of Islamic tiling patterns, industrial modules such as those used by Hector Guimard, Louis Sullivan, and Frank Lloyd Wright represent an effective extension of the requisite types of neurologically-engaging patterns. Though it hasn't been used for many decades, this form of architectural expression contains a high degree of encoded information and is thus very useful for establishing human wellbeing. Some of the older buildings that we most admire as being "hand-made" are in fact the products of a modular construction process. With today's advanced technology, this method in the hands of an architect who understands organized complexity can provide endless architectural possibilities.

(6) Natural materials from older building should be re-used. Architects must train their eye to look for those materials that help to establish the scaling hierarchy and deliver a high informational content. Every consideration should be given to incorporating materials found in architectural salvage yards into new buildings. Their informational load cannot be duplicated in new materials without incurring a considerably higher cost. This requires adjusting the design to accommodate locally-found components. Another technique is to use natural unfinished materials where appropriate. We should not try to over-control construction by practices such as cutting everything to a uniform modular size. To save a natural material (which is usually both expensive and "unsized"), we adjust our design to use the available sizes (or variety of sizes) with minimal waste. This implies developing a respect for the material over and above the authority of the design,

in much the same way as found in the early practices of Shinto carpenters. The material logic of these natural materials provides yet another level of neurological connectivity.

(7) When the use of concrete is necessary, and when it will be present at a human level, the most should be made out of its intrinsic plasticity. This is not a natural material, and therefore has to be manipulated before it can give positive sensory feedback. Instead of letting its surface present either a random texture or an unfriendly flat panel, we can mold it with patterns (as did Frank Lloyd Wright). Unfinished concrete has an informationally frustrating surface because it lacks ordered microstructure. We could moderate the unfriendly surface of raw concrete with a permanent surface or aggregate added while the concrete is still wet (a pioneer in this technique is Antoni Gaudí). On the other hand, using wooden planks to form the concrete does leave a wood grain impression, but this does not produce a visually-coherent surface because it does not have the correct fractal scaling into microstructure, and at best seems unnatural. We have in mind more ordered patterns formed into the concrete, as well as a more "natural" surface, both visual and tactile.

(8) The kind of architect who builds biophilic buildings must have a full understanding of how human qualities reveal themselves through the construction process. Whenever possible, we should give free hand to the workmen to find their own expression, such as in laying out tiles and adjusting dimensions of a window. The craft of building should once again be recognized, and craftsmen should be given the authority to mold the smaller scales of the building as it develops, so as to foster the most pleasurable feedback as they see it. Natural structure shows an infinite and subtle variation, and this potential should be extended into the use of construction materials and methods. Expression through materials requires an intimate working knowledge of the nature of these materials. This freedom extends the design process out of the hands of the architect, and was practiced in recent times by Friedrich Hundertwasser. By allowing individual input in this manner, we imbue the architecture with a life outside the frozen expression typically conceived on the drawing board. This was the way of the Master Builder, as seen in most pre-industrial buildings.

(9) The same idea can now be implemented via high technology, using computers and robotic manufacturing to generate individual components of a building. It's the similar freedom as that given to craftsmen, except that it is now made industrial through a technological basis. We can program robotic fabricators to emulate the variations in the physical mechanics of material placement, so as to endow components and materials with a similar degree of life found in pre-industrial buildings. The technology exists to create an enormous variation, which can serve in the same way as individual hands-on design created by human craftsmen. We are taking advantage of a new-found capacity for mimicking the necessary variability inherent in non-industrial processes. The same degree of life would be impossible to achieve with repeated identical components such as the standardized modules now available for construction.

(10) Unlike previous concerns about the cost of custom work and custom-made components, we have found that the technology needed to administer this work is becoming more available. We have also come to realize that this type of work need only constitute a small part of the construction to still provide the desired effect. With just a little imagination, as much as 95% of the materials used could be off-the-shelf materials

and standard components. Of course, such standard materials must be reconsidered in innovative ways to provide the greatest degree of neurological connectivity. Standard forms and building components whose dimensions and surfaces fit into the biologically-structured fractal scaling scheme can be used without alterations. The mathematical coherence established through the effective application of fractal geometry elicits the neurological engagement required for a sense of wellbeing.

(11) Several possibilities help to achieve biophilic design on the scale of a room. One is geometrical interweaving of plant life and natural features with the fabric of the building itself. We abandon the rectangular or convex footprint of a building, for a more meandering or crenellated boundary that partially surrounds gardens, verandas, and patios. If the building is large enough, then an indoor garden is possible. We focus here on a key concept. Intensify a fairly intimate scale: a complex piece of nature existing on the scale of a human being (1-2 meters in size) can make a substantial difference to our biophilic connection. We ask clients to resist their conditioned impulse toward the "purity" that is so often associated with the abstract aesthetization of many modernist designs, and to allow a high level of natural engagement to be present throughout the inhabited space.

(12) The issue is simply that of an ingrained idea about what the geometry of the environment should be. Native plants growing wild define a particular complex geometry, and this is the geometry that can best serve to keep us healthy and make us well. An unfortunate practice throughout much of the 20th Century was to identify this natural connective geometry as something that should be discarded. Instead, we must focus our intelligence and technological power towards establishing and creating natural geometry where it is absent, and reinforcing it where it already exists. The development of a natural geometry and life on buildings, via weathering, and via the invasion of plants, is nowadays seen as an unwelcome intrusion — as a sign of decay. We, on the contrary, see these as symptoms of increasing life. We can maintain the built environment from physical decay while letting it evolve in a more viscerally responsive direction.

(13) Human beings can interact with nature only if the urban geometry permits such interactions. In addition to visual line-of-sight, we pay attention to pedestrian access and the formation of urban space. Having some plant life available is only a first step: we need to make it accessible to pedestrians and design an environment in which such an interaction can be maintained and enjoyed. Frequently, ornamental plants may be seen but not approached. We must create gardens that are physically accessible, designed coherently so that it is pleasant to enter them. The worst disaster is suburban space, in which vast expanses of flat lawn and asphalt define a psychologically-hostile environment for the pedestrian. Sidewalks are exposed in the middle of this space, between the asphalt road and the forbidden lawn. Private lawns are out-of-bounds, while any bushes and trees form a protective wall around a house, instead of belonging to the public realm. We have to question this habit, breaking up such no-man's-land into well-defined urban space crisscrossed by paths.

(14) On the broader urban scale, we should again focus any distribution of units or uses away from a uniformity that privileges the largest scale. Moving away from large, purely decorative lawns, we try and design many complex natural areas; resisting the amalgamation of every plant into one "park"; resisting the alignment of everything

according to a simplistic geometry; and avoiding the homogenization of green spaces to a single plant species. We should seek instead to preserve and reproduce visual and biological complexity such as is found in natural environments. A natural (fractal) distribution of sizes applied to green spaces in the city implies the existence of very many small ones, several ones of intermediate size, and only a few large ones. Each of these green spaces should in turn have its own internal distribution, which can be achieved only by having internal complexity and variety.

To apply these and similar guidelines, many building systems and practices will have to be re-considered. The construction industry will have to overcome its built-in modularity in systems, accepted methods, and practices. For example, the building industry often keeps the architect legally removed from the building process, sometimes not even allowing access to the site. But the architect must be fully engaged from start to finish, and allowed a more active role in the processes of construction and assembly. This moves closer to the historical model of the Master Builder, which also predicates a more responsible role from the architect towards achieving wellbeing for the building's users. We want to pull out of existing systemic connections in construction practice, and re-orient architecture towards the highest degree of ordered information.

APPENDIX II: Some patterns from *A Pattern Language*.

We have selected fifteen patterns from Alexander's *Pattern Language* (Alexander *et. al.*, 1977) to summarize here. A common thread running through Alexander's work is the need to connect human beings with nature, looking to nature as a source of mental and physical nourishment. That work anticipates and supports biophilic design. Like the concept of biophilia, patterns have meaning for human life, and are not simply someone's individual preference. Thirty years after their publication, architects know about patterns without really understanding what they mean. Many patterns seem irrelevant when interpreted, as they often are, in the framework of a formal architecture; they make sense ONLY within the context of biophilic design. This Chapter gave scientific validation for these and other patterns, which should prompt their re-consideration by the architectural community. That prescient design framework contains 253 patterns in all, which can be used for generating environments adapted to human sensibilities. The following brief pattern descriptions are our own: the reader is urged to read the original several-page description of each pattern.

PATTERN 3: CITY COUNTRY FINGERS. Build a city radially instead of concentrically, with fingers of green space and farmland coming to its center.

PATTERN 7: THE COUNTRYSIDE. Re-conceive unbuilt land as one whole, encompassing farms, parks, and wilderness, and provide access to all of it.

PATTERN 24: SACRED SITES. Identify and protect sites having extraordinary importance to the community, whether they are located in a built or green area.

PATTERN 51: GREEN STREETS. Don't automatically build low-density/low-speed local roads out of asphalt, but instead use paving stones and gravel set into grass.

PATTERN 60: ACCESSIBLE GREEN. People will only use green spaces when those are very close to where they live and work, accessible by a pedestrian path.

PATTERN 64: POOLS AND STREAMS. People need contact with natural streams, ponds, and reservoirs, so these must not all be covered up.

PATTERN 74: ANIMALS. People need contact with animals, both domestic and wild, so the city must accommodate instead of discourage them.

PATTERN 104: SITE REPAIR. When siting a building, put it on the least attractive part of the lot, preserving the best of the natural environment.

PATTERN 111: HALF-HIDDEN GARDEN. For a garden to be used, it must not be too exposed by being out front, nor completely hidden by being in the back.

PATTERN 171: TREE PLACES. Trees shape social places, so shape buildings around existing trees, and plant new trees to generate a usable, inviting urban space.

PATTERN 172: GARDEN GROWING WILD. To be useful, a garden must be closer to growing wild, according to nature's rules, than conforming to an artificial image.

PATTERN 176: GARDEN SEAT. One cannot enjoy a garden if it does not have a semi-secluded place to sit and contemplate the plant growth.

PATTERN 245: RAISED FLOWERS. Flowers provide maximum benefit when they grow along frequently used paths; they must be protected and near eye level.

PATTERN 246: CLIMBING PLANTS. A building connects to its surroundings when plant life grows into it, with the plants climbing up walls and trellises.

PATTERN 247: PAVING WITH CRACKS BETWEEN THE STONES. Paving stones laid directly onto earth, with gaps between them, allow growing plants to create a half-natural environment.

We will not undertake here the task of combining the pattern language framework (these and other patterns) with our fourteen steps from Appendix I into a humanly-adaptive design tool; yet it should be obvious that this can, and should be done. Whoever is interested in this project should further refer to results on the combinatorial nature of patterns (Salingaros, 2005; 2006). It is necessary to understand those properties — their linguistic component — before patterns can be most effectively used in design applications. Patterns combine to form more complex coherent wholes; precisely the way matter organizes to form higher-level complex entities. We can apply patterns to generate an adaptive, living environment, while the patterns themselves (their evolution in solution space, and combinatorial properties) mimic the geometry of life.

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