Buildings as Habitat: Adaptive Investments in Public Health

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Abstract. Buildings kill an estimated 1 billion songbirds each year in the United States alone. Apart from the heartbreaking destruction of beautiful, innocent life, this catastrophic loss of biodiversity represents a public health emergency that tragically illuminates an all too literal clash between nature and culture. As the pervasiveness of human inflammatory conditions suggests, our hard-edged glass and concrete-dominated environments do not support our own biology either. In addition to biodiversity loss, chronic stress from extreme heat, noise, light, and air pollution degrades public health and well-being in many of our neighborhoods. From loneliness and anxiety to dementia, from hypertension to cancer, daily stress conditions erode our immune response, reduce productivity, and fray our social fabric. If evolution is any guide, culture must urgently realign with nature, prescribing a science-informed path from opportunity to obligation: all buildings, new and existing, must be future-proofed to become restorative nature-and-body-positive infrastructure investments in public health. Local ecology must be intrinsic to each ecotonal building envelope's design, supporting health by mitigating air, noise, and light pollution, naturally cooling interiors and surrounding neighborhoods, sequestering carbon, and fostering urban micro-habitat biodiversity in symbiotic realignment with the biology of all urban lives.

Keywords: resilience, health**,** adaptation, biophilic design, biophilic urbanism, neurobiology, ecotonal building envelopes, urban biodiversity, micro-habitats

This is a fundamental view of the word: It says that when you build a thing, you cannot merely build that thing in isolation but must also repair the world around it so that the larger world at that one place becomes more coherent and more whole;
and that the thing which you make can take its place in the web of nature as you make it.
Christopher Alexander, *A Pattern Language*

In December of 2021, I had the distinct honor of participating on a panel assembled by the *National Museum of Natural History* in Washington, DC as part of their exhibit "*Unsettled Nature: Artists Reflect on the Age of Humans."* Our webinar, titled "*Seeds of Potential: Art Re-imagines how Birds and Buildings Collide,*" sought to highlight *Andrew Yang's* inspirational project *The Flying Gardens of Maybe* as the starting point for a discussion about the deadly impacts of our buildings on the more-than-human world. What "Seeds of Potential" could we imagine turning what is currently a catastrophe into an opportunity to re-commit our buildings to supporting life? The National Audubon Society estimates that buildings, in the US alone, kill 1 billion songbirds each year. 56% are killed by buildings between 4 and 11 stories high, which constitutes the majority of urban structures, and an additional 1% by taller buildings (National Audubon Society, 2023), with migration mass killing events that break into the news cycle. There is something uniquely horrific in the soft bodies of our feathered fellow beings, so destined to be free in weightless flight, slamming into walls of glass. The sheer number of innocent lives lost feels like a gut punch, so painful that we tend to look away. Yang sought to pierce our apathy by honoring the dignity and personhood of each individual bird, the abrupt silencing of each beautiful voice. He honored both grief and possibility, illuminating the disastrous loss of future potential and biodiversity this daily slaughter represents. Our beautiful songbirds' deaths amount to an all too literal clash between nature and culture, and since we cannot redefine nature, it is our culture we must redefine. We know that for us as well, there will be no survival, let alone well-being, without a vibrant biosphere. And yet, many of our buildings accelerate the already rampant biodiversity

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destruction, where, among many other species, insects, and birds are suffering a decline of unfathomable magnitude. If evolution is any guide, culture must once again be placed into the service of survival by realigning our built environments with the biology of life.

Birds experience our buildings as urban cliff formations, hunting and searching for food in our gutters and under our eaves. They try to raise their families on and around our buildings, only too often with tragic results. Many of our cities are built along rivers, essentially highways for birds, who arrive hungry and depleted after long migration routes only to encounter hot, dry, and windy deserts dominated by concrete, steel, and glass and the many perils associated with those. Contemporary buildings have dramatically increased glass surfaces to please human users inside, neglecting to consider the danger this represents to other urban residents. At the risk of stating the obvious, buildings that regularly kill hundreds of birds cannot be considered sustainable buildings. They may well carry the important net-zero label but seem conceived as energy-efficient machines limited by a quantitative reductionist approach. Certainly, bird-friendly glazing solutions (see also Audubon and the American Bird Conservancy guidelines) must be obligatory for any project considering itself to be sustainable. Forward-looking cities, such as San Francisco and New York, have already passed bird-friendly glazing ordinances, which must become industry standard worldwide. Beyond that, we can do more. As the designated representative of the building industry on the Smithsonian panel, a decidedly humbling position, I sought to focus on the 'Seeds of Potential.' Every project, new and existing, represents an opportunity to get something essential right: namely, the responsibility of each building to be a benevolent community member that actively supports the well-being of *all* urban lives. Buildings that fall short of meeting this obligation must be updated via *nature-positive interventions*. Changing course to commit to an urgent re-alignment of our built environment with the biology of life, including our own biology, is the obvious path forward. The massive scale of building-bird collisions, which we as an industry apparently accept as part of 'the cost of doing business,' appears to be an unfortunately literal metaphor for the collision course we ourselves are on with nature in general and, considering public health data, with our own nature. Our reductionist approach turns out to be broadly nature-negative. It serves neither the bodies of birds nor the bodies of humans nor the bottom line. Still entrenched in a mechanistic definition of 'efficiency,' by what neuroscientist Antonio Damasio refers to as "the Cartesian idea of the disembodied mind" (Damasio, 2005), we have produced built environments our ancient body-brain struggles to associate with life-sustaining shelter, and they most certainly are nor designed to shelter anyone else. A culture accepting itself to be unmoored from its own body-nature sees fit to build machine-like environments modeled on the efficiency of disembodied software programs, adding strain to populations already immunocompromised by the corrosive effects of various other stressors, including biodiversity destruction. Why, then, do we continue to build buildings that do not support the well-being of people and, for that matter, of birds as the beautiful representatives of biodiversity? Like birds, we are biological organisms, open systems that internalize our environment with each and every breath. The COVID pandemic painfully awakened us to the fact that the same buildings intended to provide shelter can be uniquely perilous if conceived as hermetically sealed, mechanically controlled boxes. Because the weather patterns we created are killing us, we decided to live without them (Kennicott, 2023), locking ourselves away indoors and unleashing public health inefficiencies that are impossible to ignore. As we discovered, our self-inflicted dependence on technology will offer no reliable safe haven from a virus, especially with an immune response already weakened by pre-existing inflammatory conditions. Have we forgotten that our biology requires fresh air, connection to nature, and dynamic sunlight? Hardly breaking news since Florence Nightingale already promoted this with great success as a tool both for the prevention and cure of illness in the 19th century. As Dr. Joseph Allen, a healthy building expert at Harvard's T.H. Chan School of Public Health, flatly stated, "Our building infrastructure (…) we know is not designed for health" (qtd. in Anthes, 2023), a refreshingly frank admission, which begs the question: if not for health, what then *are* they designed for and what *is* our obligation as designers if not the well-being of building occupants? Daily contact with nature-rich environments is urgently needed to support a healthy immune response, especially in early childhood, so that our gut microbiome can remain the resilient protector of our health that nature designed it to be. Indoors, we may be sheltered momentarily from perils such as extreme heat by mechanical air conditioning, but at

the same time, we contribute to worsening the deadly problem of extreme heat outdoors, where birds and other non-human fellow residents must contend with rising temperatures. Their livelihoods unsheltered, their suffering unconsidered, they exist as increasingly imperiled mere decorative props viewed from our sound-proof reflective towers. Ensconced behind mechanically cooled floor-to-ceiling plate glass, we are profoundly disconnected from birdsong, from nature, and we suffer the consequences.

In 2021, the US spent an astonishing $4.25 Trillion on healthcare costs (American Medical Association & American Medical Association, 2023). Even more astonishingly, only 3.5% of that was spent on preventative services (Hargraves, 2022), a perplexingly inefficient healthcare model indeed. We spend vast sums fixing things after they break instead of preventing illness in the first place. The building industry, by contrast, has had a tradition of focusing on prevention, at least when it comes to preventing buildings from collapsing, leaking, catching on fire, etc. More recently, we have concerned ourselves with protecting the public from indoor air toxins due to molds, glues, formaldehyde, and other unpronounceable chemical compounds lurking in construction materials. We have focused on reducing a building's operational and embodied carbon footprint to tackle climate change. And yes, all building enclosures must absolutely aspire to passive house standards. But beyond that, must we not also extend our care and efforts to protect the public from buildings that are physiologically and neurologically degrading because they represent "a mismatch between our ancient genes and our modern building habits." (Sussman & Hollander, 2021) Yes, as a species, we are adaptive. However, judging from the high levels of anxiety, depression, loneliness, violence, and alienation, not to mention suicidal ideation in the population at large, things don't appear to be going that well. Evolutionary adaptation is slow, too slow, for the many profound ways in which we have departed from living conditions we are innately primed to require for health and well-being. Certainly, reasons for widespread inflammatory conditions are complex and multi-faceted, but the role of the built environment in exacerbating the problem has not been sufficiently considered, certainly not by the majority of architects and developers. Among mental health professionals, however, persistent findings that urban environments appear to be the source of an epidemic of schizophrenia and other severe psychotic conditions have drawn increasing attention (Kelly et al., 2010; van Os, 2010, qtd. in *Architecture, the Urban Environment and Severe Psychosis: Aetiology, n.d.-c*). It stands to reason that the further we remove ourselves from environments that integrate the physiologically nourishing place ingredients we evolved in and with, the more separation anxiety we seem to experience. A profound misalignment with our innate biology has occurred in our day-to-day environments. Simply put, many built environments do not offer place conditions that our ancient body-brain associates with shelter and flourishing. While a fortunate few live in leafy, tree-covered neighborhoods or aside roof terrace gardens, the less fortunate among us find themselves struggling daily against overwhelming and literally unnatural because de-natured odds. So do thousands of our beautiful songbirds, who perish each day and each night in the built environments we have deemed fit for life. They are the hapless 'canaries in the gold mine,' illuminating the folly of our deadly constructs but also the path to redemption. As a matter of public health policy, we must commit to designing resilient places that make all of us – humans and other fellow travelers - more resilient by meeting our physiological and neurological needs on an everyday basis. Nature-positive places that support urban biodiversity are equally nature-positive in supporting our own biological nature. Beyond net zero, only *nature-positive/body-positive* built environments that function akin to preventative healthcare can truly be deemed sustainable, effective, efficient, or even just plain functional in the context of public health and well-being.

Nature-Negative/Body-Negative Aspects of Current Built-Environments Contributing to a Corrosion of Public Health

The facts of nature cannot, in the long run, be violated. Penetrating and seeping through everything like water, they will undermine any system that fails to take them into account.
C. G. Jung, *Psychoanalyst*

Courtesy of evolution, we are designed to cope well with short-stress events. They can even be energizing or, in the case of sports, reduce inflammation and eliminate toxins. Prolonged and repetitive stress, however, is another matter entirely. Few mechanisms impact our immune response more negatively. Even if not consciously registered as such, low-grade chronic stress corrodes our immune defense, leading to inflammatory conditions, which underlay most, if not all, major physical and/or psychological ailments. We may survive for a time, but we will not flourish. While certainly not the only source, evidence suggests that nature-negative built environments contribute significantly to the problem of chronic stress, the health consequences of which are not currently covered by construction warranties. Approximately since the end of WWI, we have enshrined the paradigm of cognitive dualism in built environments that are profoundly out of step, and quite literally out of touch, with our embodied animal nature, creating neurobiologically mismatched places that generate in us something akin to cognitive dissonance. Accelerating technological dependencies have only deepened our disconnect from nature, including from our own nature. In her provocative book *How to be Animal: A New History of What it Means to Be Human,* Melanie Challenger alludes to the dissonance that permeates our entire nature-of-body-negative culture:

> We are animals when we embrace and when our bloodied newborns slide from the bodies of women, but not when we make vows. We are animals when we bite into the flesh of our meal, but not in the workplace. (Challenger, 2021).

We could continue: "We are animals when we breathe, see, hear, smell, and touch, but not in built environments." Cognitive dissonance is readily apparent in this statement, and yet, from this same dissonance are born design processes and 'solutions' that "direct precious little attention to considering the emotional or livable qualities of our human habitats." (Mallgrave, 2013). Cognitive dissonance seems to have become normative, enshrined in concrete, steel, and glass in the excessively noisy, hot, dry, over-lit, and de-natured environments so many of us attempt to call our home, exerting relentless underlying pressures on public health and therefore on societal equity, peace, and prosperity. In the context of public health, these are profoundly in-efficient places contributing to what Richard Louv refers to as "Nature Deficit Disorder" (Louv, 2013). Our body-minded brains, ever alert to anything "that could threaten the integrity of the organism and compromise life" (Damasio, 2010, p. 114), have noticed the misalignment, the lack of physiological nourishment. Unsurprisingly, our bodies react with an entirely appropriate biological response pre-installed by evolution: fear. Melanie Challenger writes: "How do the aspects of the immune system come to know something unknown, let alone classify it as danger? What immunologists discovered was that there are capacities to probe and identify almost on a molecular scale" (Challenger, 2021). I would hold that daily existence in an environment that forces misalignment with our neurobiological needs represents a level of chronic stress akin to trauma and may only be manageable by a degree of dissociation from one's body self. As Dr. Jan Golembiewski, a leading voice in architectural design psychology and a fellow in the *Centre for Urban Design and Mental Health,* writes: "This is where the built environment may become psychotoxic. Designers deliberately seek salience, and not only for the greater good. Design purposefully elicits responses; to impress, to spur on commerce, to alter behaviour" (Architecture, the Urban Environment and Severe Psychosis: Aetiology, n.d.-b), resulting in an overload of aggressive sensory triggers from which there seems no physical escape. Dr. Golembiewski continues:

> The fact that designers are generally unaware of the effects that their inventions have on the brain and therefore take no responsibility for this role is deeply worrying. The world of design is like a highway, where each and every driver is asleep at the wheel (Golembiewski, 2015).

In his 2023 national campaign to raise awareness about what he calls "Our epidemic of loneliness and isolation" (Office of the Assistant Secretary for Health (OASH), 2023), US Surgeon General Dr. Vivek Murthy elevates the re-design of physical elements in the built environment to foster community and connection to the first position in his framework of "foundational pillars." Many of our built environments exacerbate, if not outright foster, our archetypal fear of having been abandoned by our tribe, a fate foreshadowing death as far as our ancient body-brain is concerned. Considering the cost of chronic stress-related illness in populations, fear-inducing built environments should be considered akin to professional malpractice. Such places are characterized by a line-up of egocentric attention-seeking, nature-negative

structures, unconcerned with their responsibility to support mental health, community, or the play of children. These are not places where urban wildlife can make a living or informal and spontaneous encounters between all of the above can flourish. Instead, we are presented with hermetically sealed and mechanically conditioned constructs that leave us fundamentally out of touch with soils, seasons, climate, weather, and each other. Such places will slow our evolutionary adaption to the altering climactic conditions by creating technological dependencies that current global energy systems cannot sustainably satisfy. They force increased usage of mechanical ventilation and cooling, further exacerbating the problem of *extreme urban heat.* They also do nothing to absorb *fine particle pollution***,** nothing to mitigate glare and circadian disruption from *light pollution,* and nothing to mitigate *excessive noise*; quite the contrary. Heat and noise are reflected and amplified relentlessly. Additionally, those buildings *do nothing to support urban biodiversity.* Again, on the contrary. The catastrophic quantity of bird collisions serves as devastating testimony to our failure in this regard. There is a deep physiological connection between a bio-habitat's resilience and our own body's micro-habitat resilience (Mills et al., 2019) (Tasnim et al., 2017), a connection established eons ago. Living outside this connection compromises our health and manifests as a sense of loss, loneliness, and unease, emotions not necessarily available to consciousness but powerfully corrosive to our physiology, nevertheless. To enjoy a robust immune response, the environmental conditions surrounding us must remain within the range of dynamic homeostasis, the ancient system in charge of optimizing efficient energy management of our body-brain processes.

On an urban level, one of the insights of newer emotional models is the recognition that our emotional responses are strongly integrated with our peripheral autonomic nervous system - that is, the working of our sympathetic and parasympathetic nervous systems.
Harry Francis Malgrave, *Mind in Architecture*

We know that each of the major urban stressors has serious consequences for public health. Combined, they amplify each other, amounting to a devastating juggernaut that results in significant societal costs due to loss of well-being, loss of productivity, and even loss of life. While all of us are affected in one way or another, the distribution of stressors is profoundly inequitable, with some urban neighborhoods suffering from far greater heat, light, noise, and air pollution than others, leading to alarming discrepancies in life expectancy more determined by zip code than genetic code. Even low-grade stress, if unrelenting and repetitive, can activate ancient self-protective evolutionary responses. Triggered by daily sensory overstimulation, the somatic systems inform a physiological response, preparing us for fight, flight, or freeze by pumping high adrenaline and cortisol levels into our bloodstream. Repetitive and prolonged neurobiological stress moves from the neural into the hormonal realm, reaching deeper and deeper as "cortisol shuts down immune cells' responses." (Sternberg, 2001). This is especially damaging to the developing bodies of children (Gunnar and Quevedo, 2007). Numerous symptoms, including chronic basal hypersecretion, mitochondrial disruption, and adrenal exhaustion, can result from chronic stress-induced activation of the hypothalamic-pituitary-adrenal (HPA) axis (Herman et al., 2016). Prolonged stress activation supercharges ancient alarm responses that leave us chronically overwhelmed, anxious, perhaps even aggressive, and/or depressed. Heart rate and blood pressure can become chronically elevated. Cognitive functioning and memory become impaired (Westerink et al., 2020). Autonomic and circulatory nervous systems carry distress signals to the gut" (Madison, 2019), leading to dysbiosis, further weakening immune response. In short, the sympathetic nervous system is operating in overdrive in an attempt to protect. We are 'on edge.' Our body feels the need to be hypervigilant, which interferes with our ability to sleep. We know that a stressed and fearful mind narrows our ability to problem-solve creatively, to resolve conflicts constructively, trapping us in a vicious cycle of feeling unable to cope. We may become so alienated from our physical environment that we disengage completely into a kind of numb or frozen state. Neural inhibitory mechanisms become overwhelmed, and 'directed-attention-fatigue' sets in (Kaplan, 1995). It is, perhaps, but a small step from here to seeking refuge in disembodied virtual worlds. Data suggest that parasocial fora tend only to heighten anxiety, potentially even foster anomic tendencies in some, by dissociating us further from the birthright of our animal-body selves. (Office of the Assistant

Secretary for Health (OASH), 2023). We have made progress in developing methods that can quantify exactly how corrosive chronic stressors are to human physiology. Stress biomarkers such as skin conductance response (SDR), heart rate variability (HRV), brain MRIs, and blood cortisol levels can provide definitive information. Evolutionary biology, cognitive neuroscience, biopsychology, neurobiology, and chronobiology provide important tools designers can use to curate all built environments as intentional well-being places informed by evidence-based biology and public health data. For the most part, the diagnostic systems we developed only serve to prove to our minds what our bodies already know: our nervous systems were designed for life in nature-rich environments, a fully immersive life that engages our many senses effortlessly. Data suggest designing urban environments that align with our physiological needs, that restore and sustain us on a neurobiological level, are the only efficient places. De-natured built environments offer no neurological sustenance, no respite for our biology. They carry significant negative externalities, societal costs that render them profoundly uneconomical and, in the context of public health and productivity, unaffordable. Let us examine the main nature & body-negative stressors more closely:

Loneliness & Biodiversity Loss: In his May 2023 public health advisory, US Surgeon General Dr. Vivek Murthy establishes as fact that loneliness and isolation represent a form of chronic stress with public health consequences akin to smoking, ranging from anxiety and depression to dementia, hypertension, heart attacks, and even death. (Office of the Assistant Secretary for Health (OASH), 2023) Here again, a misalignment with our very nature has occurred. Our body-brain registers fear, ushering in susceptibility to inflammatory conditions. Isolation from the tribe represents a fundamental departure from evolutionary patterns that have evolved over hundreds of thousands of years to enhance our survival: isolation spells doom. The COVID-19 pandemic certainly worsened the trend of isolation. However, many of our built environments have long been notorious for being "depressing, brutal, ugly, unhealthy, and spiritually degrading," as Howard Kunstler already pointed out in "Geographies of Nowhere" (Kunstler, 1994), and indeed, Lewis Munford already lamented thirty years prior. As Dr. Murthy's urgent advisory indicates, we have not made sufficient progress in designing interventions that reassure and comfort our neurobiology and soothe the sense of isolation many of our urban and suburban environments seem to curate.

A related kind of loneliness afflicts us in places that are devoid of living nature. Biologist E.O Wilson argues that on a genetic basis, we are hard-wired for emotional connection with other forms of life, that our innate tendency towards *biophilia, a brotherly/sisterly kinship* with other animals, with birds, bees, and butterflies, must be considered an essential aspect of evolutionary optimization (Wilson, 2009). In the presence of biodiversity, we feel quantifiably restored. The absence of nature has the opposite effect. Our careless destruction of the biosphere notwithstanding, there lives in us an underlying longing for connection with other living systems. And yet, we have had to subsist separated from nature for so long that we have difficulty putting our consciousness finger on the exact source of this particular loneliness. Richard Louv and others refer to it as "*species' loneliness."* Until cognitive neuroscience only recently updated the paradigm, we spent some 400 years under Descartes' edicts, which declared (other) animals to be *res extensa*, material "things" devoid of consciousness, indeed, devoid of dignity or soul. Insisting, erroneously as it turns out, that the mind is of a higher order than the body, we have elevated ourselves above all other creatures only to find that it is lonely on the hard, dry, and windy tip of the pyramid we have invented for ourselves, a near perfect metaphor for a great many buildings we have constructed to take us higher and further away from earth. Perhaps we are longing to partake in the gravity-defying freedom of birds. Tragically, however, too many buildings intercept *their* freedom in midflight instead, sending millions in death spirals crashing to earth. Try as we might, we are not unaffected by this suffering. In her beautiful book "Braiding Sweetgrass," Robin Wall Kimmerer writes:

> Philosophers call this state of isolation and disconnection "species loneliness"- a deep, unnamed sadness stemming from estrangement from the rest of Creation, from the loss of relationship. As our human dominance of the world has grown, we have become more isolated, more lonely when we can no longer call out to our neighbors….We have built this isolation with our fear, with our arrogance, and with our homes, brightly lit against the night (Kimmerer, 2015).

It is certainly hard to 'call out to our neighbors' from within sealed glass towers. The more we discover about the various forms of consciousness in other sentient life, the more absurd our invented hierarchy becomes. We know that "there are interdependencies between biodiversity, (…) and public health, which lead us to argue that human health outcomes could be improved by increasing contact with biodiversity in an urban context." (Mills et al., 2019). Residents of areas burdened by low biodiversity are more likely to suffer from decreased microbial gut diversity, which, especially in children, is "a key factor in determining disease susceptibility patterns later in life" (Tasnim et al., 2017). Since 70% of our immune cells are located in the gut, microbial deprivation can usher in any number of inflammatory diseases including allergies, setting the stage for zip-code-related inequities even before day one of a child's life.

Extreme Urban Heat: Among the deadliest side effects of planetary warming, extreme heat hits the top of the list. Most of our cities and buildings are not designed to cope. On the contrary, they generate tremendous amounts of heat due to mechanical systems, lights, and the density of heat-absorbing materials such as brick, stone, concrete, steel, and heat-reflecting glass. Instead of design techniques geared toward passive survivability, our near total commitment to sealed surfaces and technology has left parched cities vulnerable to expected brown-outs and, as we discovered, to viruses, which render many a building uninhabitable under those conditions. As extended extreme heat periods multiply, soaring mechanical air conditioning usage - already responsible for the largest increase in building energy usage - creates a perilous cycle by leaking increasing quantities of CFC-based refrigerants with global warming potential 2000 times greater than carbon dioxide (Kennicott, 2023). Many cities lack sufficient natural ventilation corridors, adequate quantities of greenery, and bodies of water to facilitate the ventilation, shading, evaporative cooling, and air purification they require to offset existing hardscapes and air conditioning heat exhaust. Without adaptative measures, deaths from extreme heat, already one of the leading causes of death, could increase by more than six times in the United States. As a result of extended periods of daily average temperatures above 90°F, more than 8,500 deaths would be anticipated in a typical year under baseline climate and current demographic conditions. By 2050, this is anticipated to more than multiply by six, reaching 59,000 (Extreme Heat: The Economic and Social Consequences for The United States, 2021). Birds fare equally badly or worse since we do not afford them the luxury of air-conditioned cooling centers. Like many other animals, birds are unable to cool themselves via sweat and, without access to cooling vegetation or water, struggle to survive. In 2023 extreme heat events in the US South-West, desperate volunteers tried to save dehydrated city birds, many baby birds among them, who were near death on sizzling pavements and without access to shade or water in temperatures in excess of 100°F for weeks on end. For humans and birds alike, sleep is disrupted by prolonged heat because natural summer night cooling has become impossible in many cities. In their excellent and comprehensive paper 'Biophilic Design and Climate Change: Performance Parameters for Health' (Africa, J. 2019), the authors offer a detailed analysis of our bodies' inability to adapt to rising temperatures and the devastating public health consequences and societal costs, from cognitive and immune system breakdown to aggression, and social unrest, that arise therefrom. Due to our overreliance on mechanical rather than passive cooling strategies, rising temperatures are predicted to increase the potential for multi-day electrical grid failures, which would further "amplify mortality and morbidity risk" (Stone et al., 2023). Authors describe this as an "infrastructure failure," which will place large percentages of urban populations at serious health risk, with hospitals unable to cope. (Stone et al., 2023). Inner cities are warming twice as fast as surrounding suburbs, often with temperature differences in excess of more than 10°F. It is in our cities that the problem is most keenly felt and must urgently be solved.

Fine Particle Pollution: In addition to interior air pollutants from molds or potentially toxic building materials, the concentration of fine particle pollutants at urban street levels consistently exceeds public health recommendations. In fact, we increasingly understand that there is no "safe threshold for exposure" (Pugh et al., 2012). From gasoline car and diesel truck emissions to the microscopic particles generated by the abrasion of tires on asphalt, pollution lingers in poorly ventilated street canyons where the height of buildings often exceeds the width of streets by multiples. Low wind speeds in those canyons enable

increased deposition of pollutant particles on horizontal and vertical surfaces on both the exterior and interior of buildings. Human exposure to $PM_{2.5}$ has been linked to inflammatory respiratory conditions, including lung cancer, chronic obstructive pulmonary disease, asthma, and interstitial lung damage (Pryor et al., 2022). Since fine particle pollutants pass directly into the bloodstream, they can trigger a systemic inflammatory response, affecting tissues and organs as well as causing blood clots and cardiac and placental damage (Pryor et al., 2022). Convergent epidemiological data present strong evidence that exposure to $PM_{2.5}$ affects brain network functions and is linked to decreased cognition, dementia, and a heightened risk of developing depressive disorders (Li et al., 2021) *(Air Pollution May Increase Risk for Dementia*, 2023). Other 2023 research found that "significant correlations between $PM_{2.5}$ and antibiotic resistance were consistent globally in most antibiotic-resistant bacteria" ("Association Between Particulate Matter (PM)2·5 Air Pollution and Clinical Antibiotic Resistance: A Global Analysis," 2023). It stands to reason that other biological organisms living in polluted urban centers, such as birds, small mammals, and insects, suffer in similar, if not identical, ways.

Light Pollution: As we transition to energy-saving LED lighting systems, it is an unfortunate fact that our cities are becoming brighter at night. The magic of starry skies has gone missing from our lives. Blue-white LED bulbs of 4000-5000 Kelvin customarily used in streetlights turn night into day. The detrimental health consequences they cause are now well understood. Our ancient body-brain associates these color temperature ranges with morning and floods the body with adrenaline and cortisol, increasing heart rate and generally marshaling energy resources for the demands of the day, except it is midnight. Melatonin, the sleep hormone essential for healthy immune system activity, is suppressed. Chronic circadian disruption is a serious form of stress that ushers in systemic inflammatory conditions, making us vulnerable to any number of problematic conditions such as hormonal dysregulation, diabetes, heart disease, obesity, depression, premature cell aging, dementia, and even cancer, specifically melatonin-sensitive breast and prostate cancer (Lin & Farkas, 2018) (Shafi & Knudsen, 2019). Also negatively affected are impulse control mechanisms and conflict resolution skills. Even relatively small amounts of blue-white light exposure while sleeping affect us below the level of conscious cognitive perception, keeping the body in a semi-alerted state. In addition to the obvious public health costs, the cost of productivity loss induced by circadian disruption represents a serious problem in schools, healthcare systems, and businesses alike.

Our non-human neighbors suffer as we do, if not more. The majority of birds migrate at night, including sparrows, warblers, thrushes, and many others. The glare of our cities and electromagnetic radiation at close range interfere with their internal magnetic orientation mechanism, and the beacon effect of our night-illuminated glass towers lures tens of thousands of night-migrating birds to their deaths. There is much evidence that circadian disruption affects urban birds as well. They have been observed to feed at night in these daylight-simulated conditions, often making poor life-jeopardizing decisions or falling prey to night-marauding cats due to the stress of sleep deprivation. Similarly, night pollination is seriously affected, rendering night moth populations, of crucial nutritional importance for 60% of our songbirds, stressed and defenseless against bats in our streets, parks, and gardens flooded with blue-white light all night. Many night predators, such as owls, require darkness and quietude to hunt and simply cannot survive.

Noise Pollution: As is the case with disruptive night illumination, the corrosive impact of chronic noise on cardiovascular homeostasis does not appear to require cognitive perception. In fact, it is believed that subcortical brain areas like the hypothalamus, which has connections to the limbic, endocrine, and autonomic nervous systems, are involved in the activation of the fight-flight and defeat reactions. *Directed attention fatigue* is to blame (Kaplan, 1995). Even at low decibel levels, persistent noise is a public health hazard, disrupting sleep and contributing to heart disease, stroke, metabolic disturbances, the escalation of psychological disorders, and premature morbidity (Münzel et al., 2014). Noise hinders learning and cognition, exacerbating behavioral issues and lowering productivity and achievement. Acoustic stress is known to negatively impact 'ideational originality, a key indicator of creativity' (*An Ear For Nature,* 2018). Children are among the most vulnerable, as more than 100 million Americans' health is at risk. Continued exposure to noise does not lead to habituation. Rather, the effects are cumulative. Chronic noise is

associated with a higher risk of hearing loss, which in turn increases the likelihood of social isolation and depression - see also loneliness as a stressor above - and possibly of neurogenerative diseases such as Alzheimer's' and Parkinson's Disease. (*Noise as a Public Health Hazard*, 2022). Here again, the distribution of stressors is profoundly inequitable. As of date, the United States has no federal non-occupational noise exposure standards. Like us, birds struggle to hear each other in the cacophony of our cities. Forced to sing louder, they, too, have to expend more energy, and mating cycles can become disrupted. The same is true for all other animals trying to make a living in our noise-burdened urban centers.

The Paradigm Shift:
Design of the Built Environments is a Healthcare Profession

We intuitively evaluate the homeostatic value of a constructed environment in the same way that we might be attracted to the pleasant smell of a rose or put off by a foul odor. We cannot step outside or override the valence of our emotions without some potential consequences because our genes and a few million years of evolution have made us who we are.
Harry Francis Mallgrave, *Architecture and Embodiment*

Restoration: *The process of renewing, recovering, or reestablishing physical, psychological, and social resources or capabilities diminished in ongoing efforts to meet adaptive demands (Hartig, 2017)*
Restorative Environment*: An environment that promotes (and not merely permits) restoration (Hartig, 2017).*

In his seminal book "The Body Keeps the Score," psychiatrist Bessel van der Kolk, M.D. writes:

> If an organism is stuck in survival mode, its energies are focused on fighting off unseen enemies, which leaves no room for nurture, care, and love. For us humans, it means that as long as our mind is defending itself against unseen assaults, our closest bonds are threatened, along with our ability to imagine, plan, play, learn, and pay attention to other people's needs. (Kolk & Bessel, 2014).

A great many of our built environments seem to keep our ancient body-brain in a state of chronic overstimulation, requiring crisis-level physiological energy expenditures on a daily basis. Harry Francis Mallgrave writes: "A building can arouse our metabolic systems and demand high energy expenditure, or a building can provide a place for relaxation and comforting sociability." He asks: "…what happens in an urban environment where most buildings are designed to be active, aggressive, or even abrasive to our senses?" (Robinson & Pallasmaa, 2015). Sadly, many of us daily live the answer to that question. Both van der Kolk and Mallgrave focus on the *expenditure of physiological energy,* energy spent by the sympathetic branch of the autonomic nervous system attempting to manage repetitive high-arousal stress scenarios, energy then not available for productive, creative, or social pursuits. Energy management in the context of maintaining homeostasis is also a major theme in the work of neuroscientist and Professor of Psychology Antonio Damasio. Homeostasis is understood to be dynamic, a constant moment-to-moment internal body negotiation, a balancing and rebalancing mechanism between the sympathetic and the parasympathetic branches of the autonomic nervous system. The goal of this internal negotiation, Damasio explains, "is the formidable enterprise of managing energy." (Damasio, 2018, p 46). Information arrives via sensory and psycho-neural pathways. Cognitive neuroscience has established that much remains below the radar of consciousness. Some information rises to the level of cognitive perception as feelings, affording us diagnostic tools for conscious intervention. Feelings of well-being signify "that homeostasis is in the effective range." (Damasio, 2018, p 105). Conversely, feelings of distress, fear, and exhaustion signify that homeostasis is *not* in the effective range. The body is unable to optimize energy management toward flourishing. Damasio states:

> The brain mapping of states in which the parameters of tissues depart significantly from the homeostatic range in a direction not conducive to survival is experienced with a quality we eventually called pain and punishment. Likewise, when tissues operate in the best part of the homeostatic range, the brain mapping of the related states is experienced with a quality we eventually named pleasure and reward. (Damasio, 2010).

Judging from our stress reactions, nature-negative environments engage the "pain and punishment" side of things, resulting in health-compromising inefficiencies: too much energy is being drained away in basic life maintenance, in fortification against the background infrastructure of our lives. Physiological depletion is followed by increasing inflammation and, finally, breakdown. If our goal is to shift the unaffordable paradigm of the current status quo, we must follow the science and embrace the evidence-based 'seeds of potential,' a kind of allostatic approach utilizing adaptive, nature-positive designs that, akin to preventative medicine, strengthen our natural resilience by mediating and mitigating this unsavory cocktail of environmental stressors. We must 'treat' the ailments of our built environments as the public health epidemic they represent. This is sometimes referred to as *salutogenic design*, a design that specifically supports the causes of health and well-being. "Our buildings," Dr. Allen of Harvard is quoted to say, "should be seen as a public health tool" (qtd. in Anthes, 2023), or to paraphrase a quote by Will Rogers, president of the Trust for Public Land (TPL): Let's take sustainability out of the emergency room (qtd. in Louv, 2013, p. 265). This establishes as an obvious priority that on an everyday, everywhere basis, built environments must facilitate physiological restoration. Nothing else makes sense. To our current quantitative goals of optimizing a building's operational and embodied energy, we must add the *qualitative goal* of supporting building occupants' neurobiological energy, specifically *supporting the parasympathetic branch*, which stimulates energy restoration, relaxation, and emotional bonding. To think along with Damasio's work, we must redesign built environments to *foster neurobiologically and cognitively restorative pleasure/reward experiences* with place ingredients that keep building occupants "in the best part of the homeostatic range," a range that optimizes body energy management by reducing our heart rate and raising vagal tone. Only together will quantitative *and* qualitative goals represent a comprehensive approach toward curating truly *sustainable shelter*. While architecture as a profession is a fairly recent phenomenon, our fundamental biology has not changed since the days of the mammoth hunters. Then, as now, our place experience is governed by ancient survival imperatives via embodied cognition. The experience of place is not intellectual but visceral and immersive. This, unfortunately, is still news to many institutions of higher learning, especially those teaching design of built environments! Since at least the 1970s, science has worked with the updated paradigm of non-dualistic embodied cognition (Lakoff, 2012), returning to the somewhat obvious understanding that the mind exists courtesy of the body and that the biological condition of our body strongly influences cognition, reasoning, and psychological well-being. This changes everything about how we approach the design of the built environment! So how, then, do we renew and transform built environments to be homeostatically effective and viscerally compelling, to be restorative rather than aggressive, and to be un-demanding of negative physiological energy expenditure? What do we know about transforming built environments to optimize physiological energy management toward cognitive restoration and well-being? What place ingredients, per Damasio, curate this effective homeostatic range? Indeed, we have all voted with our feet on this. Feeling anxious, stressed, or overwhelmed, all of us long to escape to the same kind of places. Let's call them 'vacation places.' Informed by a multi-dimensional richness of sensory perceptions, our body-brain seeks to guide us toward environments most conducive to flourishing and most likely to offer conditions with the potential to correct homeostatic imbalances (Damasio, 2010, p.47). Judging from the vacation places we collectively choose, our shared physiology agrees that leafy groves, meadows, mountainous overlooks, and the edges of sparkling bodies of water are restorative places to be. We call these places 'beautiful' because embedded here are sensory patterns and place elements that offer enhanced survival opportunities. Protected and elevated perches promising sweeping views and refreshing breezes, flowing water, and vibrant plant life are key ingredients we seek. We agree that places offering dappled sunlight, ample birdsong, the sound of a waterfall or the ocean, and the presence of colorful flowers and butterflies are preferable to North-facing or indeed windowless rooms with stagnant air or rooms with glare-inducing quantities of fixed glass for example. No debate is needed. As Damasio writes: "The Diagnosis requires no special expertise but merely the fundamental process of consciousness." (Damasio, 2010, p. 59). We follow each other on the well-worn path to humanity's favorite vacation environments. Our preferences are validated by the quantifiable physiological restoration response those places elicit. These are *salutogenic places that support the causes of health***.** Our bodies know them when we see, hear, smell, and feel them. They are effortlessly

neurologically legible and perceptually fluid. Like musical harmonies, they require no explanation, translation, or education. It is as though we tune into innately familiar frequencies that our bodies instantly recognize and 'understand.' The parasympathetic branch is strengthened. We experience joy, pleasure, and playful delight. The data speak for themselves: Place patterns and place ingredients that engage that 'vacation place feeling' reduce our heart rate, raise vagal tone, activate NK cells, restore our cognition, and lift our mood. Negative air ionization must be relatively high for us to love a place, suggesting the intuitively and evolutionarily obvious: the presence of water and vibrant plant life is essential for our well-being. Research indicates that places richly bio-diverse in colorful plant and animal life support a healthy microbiome, strengthening our immune response (Mills et al., 2019), leaving us physiologically restored and cognitively refreshed. We feel gently stimulated but also relaxed. We feel well, indicating that *physiological energy management is optimized* because place ingredients curate settings *within the homeostatic effectiveness range*. (Damasio, 2010, pp. 57-60). Optimal ranges are experienced as pleasurable and valuable in health but also in monetary terms. Consider the real estate prices of properties with water, mountain, or woodland views. As Damasio explains:" Goods and actions that induce optimal life regulation will be regarded as most valuable" (Damasio, 2010). The task then is to curate built 'goods' of value for all, environments that "improve the efficiency of the adaptive response to stressors while minimizing overactivity of these systems, since such overactivity results in many of the common diseases of modern life." (McEwen, 2005). To my students, I say only half in jest: Let's design everything from schools to hospitals, offices to airports, and certainly homes to be within the quite obviously effective range of embedded vacation places ingredients. If this sounds extravagant or unaffordable, consider the inefficiencies and cost of continuing with business as usual. We already know these costs and can add increasing pressures from climate change-related extreme weather events, particularly extreme heat. Given the geographically inequitable distribution of stressors in many urban neighborhoods, it is also the only equitable path forward. Leading companies such as Google, Interface, and many more have for years, and especially in their post-Covid effort to entice workers back into offices, sought to blur the lines between work and 'leisure time,' in effect embedding vacation-style place ingredients overtly and covertly to increase productivity, an efficient strategy which aligns worker satisfaction with the company's bottom line (*The Economics of Biophilia,* 2023*.)* In so doing, they leaned deeply into the principles of *Attention Restoration Theory* (ART), which focuses on neutralizing 'directed attention fatigue' (Kaplan, 1995) by introducing nature-rich place ingredients that engage the restorative sweet spot between relaxation and stimulation. Human habitations of any kind must be infused with living plants, flowing water, dynamic daylight, high-grain wood, and other natural materials to reduce stress responses such as anxiety, adrenal exhaustion, and impaired cognitive performance (Kaplan, 1995). Considering the economics informing Fortune 500 companies' well-being-by-design strategy, it would make sense to implement this ART-based approach at the public health scale in cognitively stressful settings of any kind, especially urban settings. In the words of Dr. Jan Golembiewski: "We must design for genuine respite if we are to achieve an environmental antipsychotic effect through design" (Golembiewski, 2015).

1. *The Nature-Diet Pyramid,* reprinted with permission from Timothy Beatley, Biophilic Cities | www.biophiliccities.org

Soft Edges for Soft Bodies:
From Thigmotaxis to Ecotonal Building Envelopes

Architects are still designing the 'it,' and seldom the edge, even though it is at the edges, or ecotones, where the richest exchanges and interactions take place.
Sim van der Ryn, Stuart Cowan, *EcoLogical Design*

Like birds, we are soft, relatively small, and vulnerable bodies, equipped with ancient body-brains that have evolved over millennia for an immersive life in nature. Inexplicably, however, Architects are frequently trained to focus on other matters, such as intellectualized spatial concepts or abstract minimalist forms, too often conceived from a disembodied viewpoint courtesy of the latest design software. As Harvard biologist E.O. Wilson observed, ignorance of human biology, of the body's very architecture, and lack of awareness of the full range of human sensory experience are oft-observed traits in even the most celebrated creative artists (Wilson E.O., 2017). As architects, whose work arguably leaves an indelible day-to-day imprint on the public, we are obligated to educate ourselves about the biologically ancient and visceral nature of human place experience and the physiological impact of our work on the public we serve. We understand how to design and retrofit thermal building envelopes that meet net-zero operational & embodied carbon goals. However, as the disastrous biodiversity loss caused by the perimeter of our buildings proves, we must give equal and urgent consideration to the exterior surfacing of those building envelopes: are they restorative or, in fact, destructive? It is, after all, the hard and unforgiving edges of our buildings that kill all those beautiful songbirds. It is the mirrored reflections, the beacons of light our buildings become at night, the see-through illusions of corner glazing, glass railings, and glass atria, especially if filled with interior greenery, which birds seek to reach in vain.

It turns out we, too, are deeply affected by edge conditions. Like other animals, we experience the world through somatic sensations, yearning for soft comfort, nourishment, and shelter. Much focus is on the *physiological quality of enclosures*. As a mom, I have fond memories of tucking my children into their beds while other babies, those of the feathered kind, were tucked into *their* nests, ever so skillfully woven by their parents into the leafy ivy curtain on the other side of the very same wall. As a biophilic architect, I have given a great deal of attention to the design of edge conditions that shelter human, plant, and bird life. Like other animals, we experience the stress of disorientation, a sense of exposure, or of feeling trapped when edge conditions are ambiguous, reflective, forbiddingly closed, or defy supervision such that danger could lurk in dark crevices. Such edge conditions create inefficiencies in terms of physiological energy expenditure. They elevate cortisol and are consequently guaranteed to be unpopular. As such, they are reliable predictors of economic failure in building projects. In *Cognitive Architecture,* Ann Sussman and Justin Hollander discuss the example of Boston's City Hall, whose brutalist, scary-desolate edge conditions have single-handedly wiped out a vibrant historic downtown: "The plaza's urban renewal history illustrates the high cost we and future generations pay when planners and architects do not appreciate their clients as evolved mammals with embedded reactions to place " (Sussman, A., & Hollander, J. B., 2021, p.35). The example of Boston's City Hall and similar places makes abundantly clear that the economic success of any built environment is directly proportional to its successful alignment with innate biological preferences. Damasio writes: "My hypothesis is that objects and processes we confront in our daily lives acquire their assigned value by reference to this primitive of naturally selected organism value" (Damasio, 2010, p.52). To put it simply, places that make us feel trapped, exposed, or unprotected do not permit physiological energy optimization. Instead, they represent an unsustainable waste of human energy and material resources. Edge conditions are where much of this plays out.

In biology, the term *Thigmotaxis* refers to "The motion or orientation of an organism in response to a touch stimulus" (Oxford Dictionary). In design, Thigmotaxis refers to our relationship to horizontal and vertical edge conditions. Sussman and Hollander write: "When it comes to edges, biologists classify humans, exactly like other mammals of prey, as thigmotactic, or a 'wall-hugging' species" (Sussman & Hollander, 2021). Sussman and Hollander describe this in evolutionary terms as another "energy-conserving strategy and a survival one," a common biological trait that can be observed in organisms as

ancient as bacteria and as recent as mammals. All of us orient on edge conditions, and it turns out we favor a particular kind: I call them *engaged edges* because they permit us to *engage neurologically* in a manner aligned with biological flourishing. They engage our body-brain, which is constantly scanning for survival-related place information with the goal of physiological energy conservation. Primarily, we seek to establish a neurological relationship with place that promises life-sustaining shelter. It appears that nature has designed us to instinctively seek out 'soft' and permeable edge conditions that offer the potential for retreat (*refuge*) as well as observation of opportunity (*prospect*). Research indicates that *refuge* generates a higher relaxation response than *prospect.* Just like our fellow animals, we feel exposed in wide-open, unprotected spaces and prefer to move along edges, hedges, or walls, assuming those walls have intermittent and readily available openings that permit us to take cover in case of inclement weather or perceived danger. Think thickened wall conditions with variations on the theme of porous spatial layering, such as shady colonnades, plant-covered arbors, trellises, porches, balconies, verandas, pergolas, or the like. In other words, we like our edges body-positive: enriched, even embellished, offering a measure of protected depth and the flexibility, variability, and refuge of *transitional* conditions between inside and outside depending on usage, weather, and circumstances. We like options! Places with 'soft' edges are *neurologically legible*. More likely than not, they support a reduction in our heart rate because they simultaneously address our need for refuge & prospect (Appleton, 1975), personal safety, and community (also related to safety). We are innately drawn to these places because we experience a relaxation (pleasure/reward) response. *Our physiological response indicates that place conditions are within the homeostatically effective range and likely to enhance flourishing.* Understanding our biological preferences is key to creating restorative, meaning physiologically efficient design solutions. Taking a biomimetic approach, let us examine how nature designs edge conditions that support, rather than destroy, life:

On both a macro and micro level, nature favors permeable edge conditions. We refer to such places as *Ecotones.* These are transitional spaces, open boundaries that facilitate life and energy transfer in both directions, fostering especially biodiversity-rich conditions. Van der Ryn and Cowan write: "An ecotone is a soft overlapping of very different regions. Like patches of watercolor on wet paper, different regions intermingle in an ecotone to create a new spectrum of colors." (Van Der Ryn and Cowan, 1995). Fast forward to our cities: those that are successful in translating the qualities of 'soft edges' into built environments tend to be beloved and memorable. Those unsuccessful are experienced as bleak, uncomfortable, and inhospitable. Our biological needs are not supported here, and our body informs our consciousness to that effect. We do not like these places. They feel stressful because they quantifiably are (Ellard, 2021). Neither health nor commerce will reliably thrive. If we live here, it is often not by choice. To be well, we require built environments that are vibrant and feel alive, buildings that surround us with the equivalent of a 'second skin': a transitional layer that protects as it connects, affording experience of the ever-changing experiences of seasons, weather, community, and more-than-human life.

How does nature develop ecotonal edge solutions akin to building envelopes? Let us consider the bark of a tree: it shields from wind, weather, and ultraviolet rays while also protecting the interior 'climate' of the tree in terms of moisture, nutrient levels, and fungal growth. Additionally, bark functions as a micro-ecotone, providing food and shelter for insects and birds, as well as serving as a canvas for a rich diversity of epiphytes (Petruzzello, 1998) such as mosses, liverworts, lichen, and some ferns. Epiphytes do not trap moisture or harm the tree. As a symbiotic system, this living layer enriches the tree by providing additional soil nutrients, establishing a microhabitat on each trunk and branch, which sequesters carbon. Epiphytes achieve microclimatic improvements by reducing daytime vapor pressure deficits (VPD) and moderating temperature variations (Stanton et al., 2014). What if we took a similar approach to make our buildings more resilient? Sussman and Hollander write: "People use buildings as orientation devices and protection screens" (Sussman & Hollander, 2021). So, let us future-proof our buildings by adding 'protection screens' with qualities similar to the bark of a tree, albeit more transparent to suit human needs. Let us take our favorite thigmotaxis pattern, *refuge & prospect*, and add the dynamic sensory experiences of dappled sunlight through a leafy curtain of vegetation swaying in a cooling breeze. Add the daily experience of seasons and weather, the chirping of birds, the humming of bees and butterflies, and the scents and negative air ionization of plants, and you have the 'vacation ingredients' of a vertical garden that can be implemented

2. Photos by Author

just about anywhere, even conceived as a vertical rain garden if conditions require. Clothed in verdant *Ecotonal Building Envelopes (EBEs),* formerly hard-edged buildings are transformed into soft and vibrant places, alive with place ingredients offering enhanced well-being conditions that mitigate air, noise, and light pollution, naturally cool interiors as well as surrounding neighborhoods, and foster micro-habitat biodiversity in symbiotic realignment with the biology of all urban lives.

From the hanging gardens of Babylon to the ivy and grapevine-covered walls of historic houses including my own, vegetated buildings are hardly a new building typology but are still altogether too rare. Considering how many urban stressors they mitigate, this is perplexingly out of step with the economics of resilience. Much misinformation persists regarding potential façade damage, leakage, or bug infestations. As successfully completed projects prove, all of these can be avoided by having experienced experts from various disciplines on board from day one of the design process, focusing on technically correct detailing, positive drainage, climate and elevation-appropriate plant selections, and state-of-the-art irrigation, and filtration systems. What if we learned from local hills and mountains about the kinds of vegetation that thrive in high, dry, and windy places? Remembering that birds nest and hunt from tall buildings as though they are cliffs, we can follow their lead. In this context, it is interesting to consider biologist Jeremy Lundholm's work on "The Urban Cliff Hypothesis" as a "Habitat Template" (*Urban Habitats -- Green Roofs and Facades: A Habitat Template Approach, n.d.).* To serve the twin goals of fostering public health and biodiversity, the human designer assumes a posture of humility, first learning from nature, then stepping back to permit nature to provide the design language of a façade that is seasonally changing and beautifully alive. As van der Ryn and Cowen write:" By designing ecotones, rather than hard edges, we intensify interactions. We bring together a greater variety of life…. we facilitate the flow of materials, energy, and information that can catalyze design processes." (Van Der Ryn and Cowen, 1995). Well beyond mere imagining, many beautiful vegetated tall buildings have been built worldwide. Renowned botanist Patrick Blanc spearheaded a version of EBEs he calls "vertical gardens" (Mur Végétal), providing cliff-like landing pads and nesting opportunities for urban residents, such as birds, squirrels, and pollinators, and well-documented health and community-building benefits for humans. In describing *One Central Park* in Sydney, Australia, currently the tallest vertical garden in the world designed by Patrick Blanc in concert with the design teams of Foster & Partners, Ateliers Jean Nouvel, and PTW Architects, University of

Virginia's Professor of Sustainable Urban Communities, and Founder and Executive Director of *Biophilic Cities* Timothy Beatley writes:

> The green walls increase energy efficiency, serving as natural insulation for the building, as well as an air filtration system that transforms pollutants into useful plant fertilizers. Providing jobs and utilizing local plant species, economic stimulus and educational opportunities coincide, providing a connection between city dwellers and the natural flora of their habitat (Beatley, 2016).

Blanc refers to his work as 'Living Architecture' and asks us to "imagine a building that grows, sprouts and flowers, changes colour with the seasons, or sheds leaves in winter as though magically alive with petals, vines, and buds." (Vertical Garden Patrick Blanc n.d.). Italian architect Stefano Boeri designed and built

3. Photos by Author

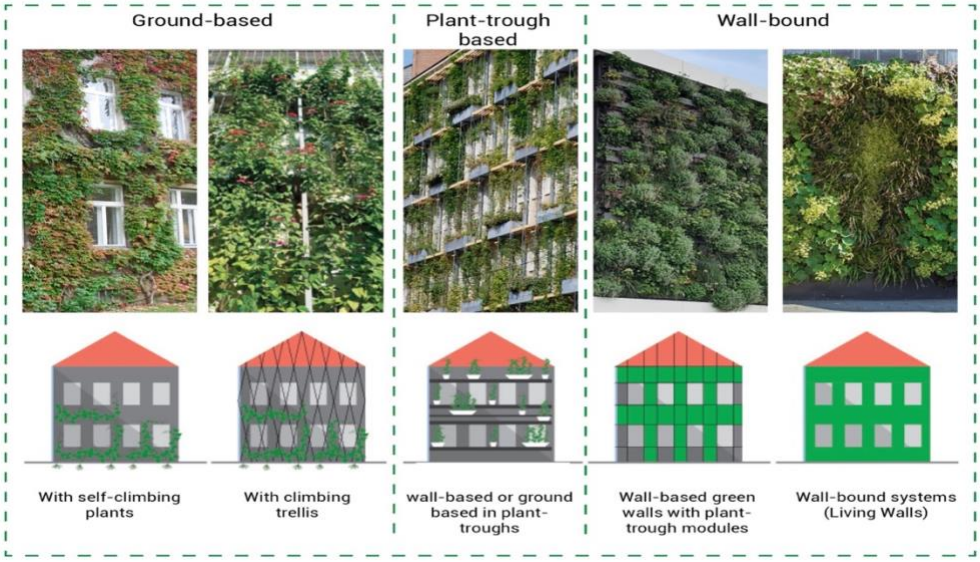
the popular "Vertical Forest" (Bosco Verticale) buildings, such as the Bosco Verticale towers completed in 2014 in Milan and several more. Boeri explains that the Bosco Verticale houses the nests of over 20 different bird species, in addition to a plethora of plant species, whom he views as the building's main occupants (Lubell, 2020). Architecture firms such as *WOHA, BIG, MVRDV, Ateliers Jean Nouvel, Vincent Callebaut, Smyrlis Architects, Ingenhoven Architects, Enrique Browne, Sheppard Robson*, and others are designing and building vertically vegetated designs. Considering the urban stressors we increasingly face, we must urgently scale up this effort, replacing any lingering luxury label with a public health mandate.

EBEs include both *extensive* and *intensive Vertical Greening Systems* (VGS) as well as *extensive and intensive Living (Green) Roofs.* Living roofs support urban biodiversity and are important stormwater management and urban cooling tools. Likewise, VGS can be designed as vertical rain gardens. Well-documented examples of large "stormwater-powered" living walls designed in direct collaboration with water engineers are the 21-meter-high wall in the Victoria neighborhood of London (Andrews & Andrews, 2022) and the façade of the Enni Headquarters in Moers, Germany (Turner, 2023). Elaborate intensive wall-bound VGS (Living/Green Walls) are fairly complex to install and maintain. A focus on the greater simplicity and affordability o*f extensive ground-based VGS (Living/Green Façades),* as far as installation and maintenance, might be the most adaptive path to meet the goal of wrapping the existing stock of naked buildings in cooler, softer, more resilient clothing. These *gound-based systems* consist of climbing vegetation either a) self-climbing on building facades *(direct/two-dimensional Green Façade)* or b) supported by a secondary trellis *(indirect/double-skin/three-dimensional Green Façade)* (Medl et al., 2017) (Bustami et al., 2018) (Susorova et al., 2013). In both cases, vegetation grows from ground-based (including

sidewalk-based) planters or planting strips that are watered via rainwater directly and/or rooftop or parking lot collection cisterns, making them drought-resistant. Root systems are protected by native surface plantings. Several cities, such as San Francisco, have already implemented 'Grey2Green' initiatives, issuing sidewalk greening permits after any potential conflicts with utility infrastructure have been resolved. N*on-deciduous, direct/two-dimensional Green Façades* create a thermal layer that both warms building interiors in winter and cools them in summer. In the Northern Hemisphere, *deciduous indirect/three-dimensional Green Façade Systems* add a soft double-skin-screen of vegetation that is especially effective in lowering interior glare and summer temperatures on South and West-facing glass walls, otherwise difficult to shade due to the low sun angle in mid to late afternoon.

All VGS provide noticeable evaporative cooling benefits through plant leaves for both building interiors and surrounding areas that other shading systems do not offer, which "improves the urban microclimate…and acts as n*ear-natural air conditioning systems"* (Kg, 2022). VGS also provide protection against UV radiation and pollutants, may thereby inhibit material deterioration, and serve as effective deterrents to graffiti. The lightweight trellis structure of ground-based VGS consists of either stainless steel cables, mesh, rope, or wood trellis, depending on height, climactic conditions, and wall surface materials. Even the most mundane buildings can thus be transformed into a *vertical micro-habitat.* Modular cable and mesh solutions can easily be adapted to follow biomorphic building forms (Perez & Perini, 2018) (*Greenscreen - an Innovative and Unique Modular Trellising System*, 2023). To protect the birds we invite, Audubon Pennsylvania's Connie Sanchez recommends the distance between building wall and *Green Façade System* not to exceed 3 feet and to add bird-safe glass as a matter of course.

An interesting example of a *ground-based, double-skin/three-dimensional VGS in combination with intermittent plant troughs* is the award-winning South Elevation of the Institute for Physics at the Humboldt



4. Image: https://efb-greenroof.eu/green-wall-basic

University in Berlin, Germany, designed by Augustin & Frank and completed in 2002. As an ecological model, this VGS system's performance was studied and documented for 8 years by an interdisciplinary group of researchers from the Technical University (TU) Berlin and the Humboldt University (HU) Berlin (Kg, 2022b). From April through October, lightweight planters are individually drained and collectively misted via a roof rainwater collection system. Due to urban soil contamination in the vicinity, stormwater evaporation was only permitted via phytoremediation. 950 climbing vines were planted, most of which have reached full building height. Compared to manual or automated textile shading systems, the building's deciduous plant screen, supported by a combination of wood, bamboo, steel cables, and rope, achieves significantly higher interior summer cooling of the glass facade (Kg, 2022b). Additionally, the VGS

provides evaporative exterior cooling, establishes a vertical micro-habitat for birds and pollinators, filters dust, absorbs noise, mitigates glare both inside and out, and sequesters carbon. It also provides the delight of dappled sunlight patterns, the rustling of leaves, the scent of wisteria blossoms, and the chirping of birds.

5. Institute for Physics at the Humboldt University in Berlin, Germany, 2023 | Photo Credits Mascha Creutz

Nourishing the Seeds of Potential:
Micro-Habitat Buildings are Adaptive Investments in Public Health

……all organisms on our planet are fundamentally similar. It's kinship that makes our immune system work.
Melanie Challenger, *How To Be Animal: A New History of What it Means to Be Human*

In the "Geography of Nowhere," James Howard Kunstler bemoans the results of a building and development ethos that "has nearly wrecked the human habitat in America." The term 'habitat' is of interest. Oxford Dictionary defines 'habitat' as "the natural home or environment of an animal, plant, or other organism." National Geographic states: "A habitat meets all the environmental conditions an organism needs to survive" (*Habitat*, n.d.). As the public health consequences of daily urban stressors indicate, the urban habitat, currently home to 50-80% of human populations depending on country, and projected to double by 2050 (*Overview*, n.d.), needs salutogenic intervention. In habitat restoration interventions for other biological organisms, we seek to reestablish the living conditions that permit those organisms to flourish in alignment with their evolved physiological nature. The *economics of resilience* would suggest that we take the same approach to re-imagining human habitat as a place that fosters neurobiological energy optimization. In the context of built environments, the most comprehensive definition of 'habitat' I am currently aware of shall be quoted here in full:

> Habitat, in this context, encompasses the materials, structure, and program of the building; management of site metabolism, including energy needs and waste flows; concordance with the surrounding environment, both within the building and beyond the building façade; support for on-site biodiversity, from micro to macrofauna…; and perhaps most of all, a recognition that these features communicate habitability and community to human occupants through eons of evolutionary priming and that this appeal is both desirable, comfortable, and health-promoting" (Africa et al., 2019).

This deserves repeating: "on-site biodiversity, from micro to macrofauna, (…) communicates habitability and community" (Africa et al., 2019). While the need to significantly increase urban tree planting is self-evident, their placement in poorly ventilated streets may present challenges as densely foliated canopies

can restrict airflow further, or there may not be sufficient space to sustainability support their root balls. The ideal way to integrate easy nature into tight and densely populated areas is to add *Ecotonal Building Envelopes (EBEs)* at scale to the underutilized real estate of acres of currently empty facades and roofs, transforming urban canyons into leafy bowers to improve the microclimate of each neighborhood and the city at large. Rather than isolated islands, a contiguous vegetated blanket can be folded across each city to cool, quiet, and delight, amplifying the individual contribution of each building towards a more healthful, more biodiverse urban environment where all may breathe more freely. *Terrapin Bright Green* uses the term *Biophilic Urban Acupuncture* to illuminate the salutary ripple effect even small-scale nature interventions generate: "Just as the practice of acupuncture is aimed at relieving stress in the human body, the goal of biophilic urban acupuncture is to relieve stress in the built environment "(Walker, 2016). *Indirect/double-skin Green Façade Systems* are especially physiologically advantageous in this regard as they permit an enhanced refuge experience sheltered by a transparent leafy veil that protects from prying eyes and the sensory overload of the street.

Let us explore the benefits of EBEs in response to the specific urban stressors discussed above. It should be noted that EBEs contribute on a multi-sensory level, and thus, the below categories all act in concert to support public health.

From Loneliness to Biophilia: A 2022 Columbia University study found that ecosystems, especially those experienced as children, serve as object relationships and that people are less able to safeguard these relationships for their own well-being when society does not recognize their significance (Bodnar et al., 2023). Through eons of evolutionary priming, *biophilia* represents our innate emotional connection to the biosphere that sustains our lives. As the Columbia study suggests, philia is family, a community of relationships crucial for personality development and directly connected to well-being.

Suffering can open our hearts. During the isolation of the pandemic, many of us (re)discovered that nature offers ready companionship. We took to birdwatching, made friends with the equally lonely pigeon arriving daily on our apartment's fire escape, or struck up a conversation with the baby squirrel, whose playful curiosity charmed us to a smile. Perhaps our COVID loneliness persuaded us to reconnect with our innate biophilia. Hopefully, it opened our eyes to the well-documented mental health benefits of leveling the playing field between 'us' and 'them,' to engage in up close and personal relationships with the buzzing, feathered, and furry fellow members of our urban community. "The intentionally cultivated ecotone promotes contact among people and between people and nature," Van der Ryn and Cowan wrote (Van Der Ryn and Cowan, 1995). EBEs foster community, community with nature, and community among people. Building maintenance shifts towards stewardship, offering physiological benefits far beyond the reach of spreadsheets and bottom lines. People who reside in highly variable green environments have 37% lower odds of being hospitalized for cardiovascular disease (Yaeger et al., 2020). As we know from our vacations, nature has a way of bringing people together with ease. From macro to micro, nature experiences restore as they delight, inspire as they awe. Awe gives our lives meaning by enticing us out of our lonely all-about-me-focus to connect with something larger than ourselves. We begin to belong again. Awe experiences make us more cooperative, more generous, and, so it turns out, profoundly strengthen our immune response. The groundbreaking work of UC Berkeley Prof. of Psychology Dacher Keltner must be mentioned here. Keltner found that awe experiences engage the parasympathetic nervous system, support the vagus nerve, and release oxytocin, thus reducing inflammatory cytokines (Keltner, 2023). The homeostatic motivator of *pleasure/reward* kicks into full swing. Taking these significant health benefits out of the realm of the occasional into what Prof. Keltner refers to as "everyday wonder" falls squarely into the domain of every designer's responsibility. By applying a relatively simple recipe of ingredients, EBEs offer the possibility for multi-sensory, cortisol-reducing *everyday wonder* adaptable to a multitude of needy architectural settings. As Kate E. Lee's research of 'micro-breaks' suggests, mere 40-second views of nature have the power to improve cognitive function (Lee et al., 2015). Imagine the health benefits of frequent casual glances through seasonally dynamic leafy curtains that delight building occupants with gently swaying light patterns. Imagine the ability to partake in the lives of birds, praying mantes, and butterflies up close, on the 8th or 10th floor, and in the comfort of your own home. Awe experiences are homeostatically effective via

involuntary attention & soft fascination, key components of *Attention Restoration Theory* (ART) (Kaplan, 1995) (Basu et al., 2018), As such, they contribute to overall stress-reduction and cognitive restoration. Richard Louv calls this effect "Nature's Ritalin" (Louv, 2013). He writes: "Greenery in a child's everyday environment, even views of green through a window, specifically reduces attention deficit symptoms" (Louv, 2013). We have entered the realm of *salutogenic design*, and EBEs make this possible and affordable daily and at scale.

The biodiversity of another community is in urgent need of support: our bodies' microbiotic community, which we know to be impaired in de-natured urban populations. Biodiversity interventions enhance immune regulation and can be viewed akin to preventative medicine:

> …restoring urban biodiversity provides a low-risk and low-cost investment that is likely to rewild urban microbial processes and have potential to pay generational health dividends. We believe that these restoration investments are imperative for tackling the ongoing decline in urban green spaces, rapid growth in urban populations, and increases in microbially-mediated non-communicable diseases (Mills et al, 2019).

As an essential aspect of public health policy, all urban and suburban centers should follow the lead of biophilic cities San Francisco, Singapore, Los Angeles, and others to establish a city-wide biodiversity policy *(San Francisco Biodiversity Program & Policy, 2023) (Handbook on the Singapore Index on Cities' Biodiversity,* 2008*)*, comprehensive goals and guidelines integrating wild nature into urban infrastructure, not just on the ground but on all available surfaces in the form of vegetated building façades and roofs.

From Extreme Heat to Natural Airconditioning: On a hot late August day in Pennsylvania, I am gazing through the blooming vines of *Clematis Sweet Autumn,* filling the air with the scent of honey and the buzzing of bumblebees. We planted the prolific vine to shade the South and West facing glazing of our home, an effective and delightful curtain that, along with ivy-covered East and North facing walls, keeps our interiors naturally airconditioned. It also provides popular nesting and overnight accommodations for local birds. Experimental studies reveal that using plants as part of the building envelope significantly reduces ambient temperature close to the facade as well as interior temperatures, materially improving energy efficiency (Susorova et al., 2013). The temperature of building façades shaded by VGS was shown to be up to 7°C (12.6°F) cooler than ambient air, thereby also positively affecting neighboring buildings by reducing heat reflection. Relative to shade sails, for example, evaporative cooling contributed 25–35% of the total cooling achieved by Green Façades. The thermal advantages of Green Façades suggest meaningful contribution to the sustainability of building designs and represent an *effective natural remedy for urban heat islands* (Bakhshoodeh et al., 2022). Even cities in humid climates benefit with a temperature decrease of 8.4°C measured in Hong Kong, when both roofs and walls are vegetated (Alexandri & Jones, 2008). The air space EBEs create between building wall and a double-skin Green Façade could be designed to generate a wind-assisted stack effect, pulling hot air out of poorly ventilated urban canyons. In all climates studied, the combination of green roofs and green walls leads to the highest mitigation of temperatures. Air masses enter urban canyons pre-cooled when roofs are also covered in vegetation (Alexandri & Jones, 2008). It is of crucial importance to apply these techniques at scale:

> If applied to only one unit block, green roofs and green walls can create a small area of mitigated temperatures to the urban heat island effect, as has been shown in this microclimatic study. If applied to the whole city scale, they could mitigate raised urban temperatures, and, especially for hot climates, bring temperatures down to more "human-friendly" levels and achieve energy saving for cooling buildings from 32% to 100%. (Alexandri & Jones, 2008).

The potential to measurably lower estimated levels of heat illness and death in anticipated electricity blackouts during prolonged extreme heat events lies in widespread interventions that improve evapotranspiration, shading, and solar reflection in built environments (Stone et al., 2023). Additionally, the *Living Architecture Performance Tool* recommends the integration of mechanical HVAC systems with living plant systems, such as strategic placement of HVAC units "to reduce the temperature of intake air" (*Living Architecture Performance Tool - Green Infrastructure Foundation, n.d.) (Wong, Tan, Chen, et al., 2010).*

From Fine Particle Pollution to Phytoremediation: Through a variety of mechanisms, including accumulation, immobilization, and degradation, plants reduce the toxicity, mobility, and volume of aerosolized contaminants. Because only solar energy is required for these biological processes, phytoremediation is more affordable than engineering-based remediation techniques (H. Lee et al., 2021). Air pollution in urban canyons is affected by building surface materials, the ratio of building height to canyon width, and the resulting velocity of in-canyon air:

> Pollutant concentrations can be reduced by increasing dry deposition to surfaces. Compared to controlling emissions or enhancing dispersion, relatively little attention has been paid to deposition as a pollution control measure. An effective and accessible means of achieving an enhancement in pollutant deposition is to plant additional vegetation (Pugh et al., 2012).

Models show that vegetating street canyon walls offers significant potential for upgrading air quality values, particularly at low wind speeds when the effect of in-canyon vegetation is heightened. The model predicted reductions in NO_2 and PM_{10} concentrations of up to 40% and 60%, respectively, indicating that canyon wall vegetation forms a natural buffer against high-pollution episodes, frequently associated with low wind speeds and related acute impacts on human health (Pugh et al., 2012). Depending on species and size of leaves, VGS can serve as self-cleaning façades via autumnal leaf fall. Unsurprisingly, model results demonstrated that greening of urban in-canyon wall surfaces is more effective than greening of roofs in terms of reducing street-level pollutant concentrations because it acts directly upon the relatively small volume of air in the canyon (Pugh et al., 2012). In tight canyons: "Vegetated walls can improve canyon air quality more than street trees because better vertical airflow out of the canyon can be achieved "(Pugh et al., 2012). VGS also *mitigate urban dry island* (UDI) effects, characterized by drier atmospheres (less moisture and a greater vapor pressure deficit (VPD)), necessitating intensified urban greening efforts (Luo & Lau, 2019). Additionally, VGS *sequester carbon, enhance canyon oxygen* levels, and *add negative air ionization*. Eva Selhub MD and Alan Logan ND write: "Researchers…linked the regional abundance of negative air ions to improved human health and longevity" (Selhub & Logan, 2012). Increasing levels of negative air ions *positively affects Seasonal Affective Disorder and depression* (Terman & Terman, 1995), as well as slowing *the aerosol transmission of Influenza and COVID viral particles* (Zhang et al., 2019).

F*rom Light Pollution and Glare to Dynamic Dappled Light:* To protect night-migrating birds*, three-dimensional Green Façade Systems* that add a double-skin-screen of vegetation can be effective because they reduce the overall glare of cities, diffusing the killer beacon effect of each illuminated building. Softened edges offer a softer landing in the buffering plant curtain that invites and then keeps its promise to shelter and even feed. As mentioned above, the maximum distance between building wall and plant curtain must be less than 3 feet to protect birds. From inside, our own circadian well-being can be shielded from the immediacy and glare of city lights. During daytime, the interior light quality becomes nuanced and softened, mitigating the uncomfortable glare-and stress-inducing condition of the single sun orientation so many urban rooms are limited to. Dappled sunlight patterns will move across our spaces, making breezes visible, thereby adding neurologically relevant circadian, seasonal, and weather-related information that supports our immune response and enlivens otherwise lifeless interior spaces. When all buildings adopt these adaptive mitigation strategies, we might be able to see the stars again, affording ourselves the *soft fascination* of *every night wonder awe experiences* we know to be associated with *Attention Restoration Theory (ART)* because they engage *ancient pleasure/reward motivators,* deeply meaningful because connected to physiological energy optimization.

From Noise Pollution to the Twitter of Birds: The first thing one notices when approaching a leafy building is the chirping of little birds who are busy making a life here. There is a lot going on here. It's a community place that delights many of our senses. The key word is *life.* The building *feels alive* because it is. Our body-brain associates birdsong with well-being, with freshness and springtime, and with things generally being 'ok' since birds have a better view than we do and stop singing when peril invades the

neighborhood, as every squirrel and chipmunk already knows. Anyone who has observed a cat or a hawk entering a bird-filled yard can testify to the immediate silence that ensues. As sound branding expert Julian Treasure puts it in one of his TED talks: "When the birds are singing, we feel alert. It's a good, body-relaxed, mind-alert state." He counts birdsong as one of our three favorite sounds (the other two being water and wind). Daily interactions with birds are linked to lasting mental health improvements (Hammoud et al., 2022). Whereas traffic noise was linked to depressive symptoms, birdsong was found to reduce anxiety and paranoia (Stobbe et al., 2022). We can conclude that *birdsong engages the homeostatically effective pleasure/reward motivator*. It is another of our 'vacation place ingredients,' fostering the *soft fascination* associated with *Attention Restoration Theory (ART)*. Additionally, the combination of façade vegetation and the layer of air between plants and building wall can function as a sound-absorbing barrier. Depending on leaf size and density of vegetation, plants are effective at deflecting and absorbing sound waves, especially higher frequencies. A comprehensive 2010 study found that:

> The sound absorption coefficient of the vertical greenery system in the reverberation chamber has one of the highest values compared with other building materials and furnishings. The sound absorption coefficient increases with increased frequencies. In addition, it is observed that the sound absorption coefficient increases with greater greenery coverage (Wang et al., 2010).

According to economists who examined health care costs and productivity losses due to heart disease and hypertension, a 5dB reduction in noise levels could generate a $3.9 billion annual benefit (Baumgaertner et al., 2023).

Tending the Seeds of Potential

I like very much the idea of a "blooming building" and the notion that we might judge a building … by whether and how often it blooms.
Timothy Beatley, *The Bird-Friendly City*

I have approached this topic from a primarily human-centric point of view because, for most of us, this is the normative narrative. Having subscribed to this narrative, however, we have become a lonely species, missed many opportunities, and created enormous challenges for ourselves and all other organisms on this planet. The narrative of human exceptionalism has quantifiably outlived its utility if ever it possessed any. It has been debunked by the extractive, neuro-biologically inefficient environments we have created and the current state of our planet in general ("Earth Beyond Six of Nine Planetary Boundaries," 2023). As Melanie Challenger states: "If we want something more like a mutualistic approach to the life around us, we will have to see into the needs of other organisms." (Challenger, 2021). Evolving into an adaptive, mutualistic approach permits progress with greater efficiency and, indeed, with the humility required to understand and implement biomimetic win-win solutions that honor and protect the dignity and well-being of all lives. As we stand at the dawn of disembodied intelligence, many of us discover that we yearn to define the best of human nature in biological and emotional kinship with other animals rather than with machines. Interestingly, this occurs at the exact moment we learn so much more about the language and consciousness of (other) animals. We have (re)emerged into a world that is humming with the conversations of fellow thinking beings, however enigmatic (Shah, 2023). In *God, Human, Animal, Machine,* Megan O'Gieblyn observes:

> Today, as AI continues to blow past us in benchmark after benchmark of higher cognition, we quell our anxiety by insisting that what distinguishes true consciousness is emotions, perception, the ability to experience and feel: the qualities, in other words, that we share with animals. (O'Gieblyn, 2022)

The extraordinary opportunity of this moment lies in the recognition that our evolutionarily-primed biophilia, our innate ability to recognize and value our shared ancestry with other living organisms, is the exact quality that illuminates the path we need to walk toward the survival imperative of reciprocity, placing

our equally evolutionarily-primed self-interest into the service of stewardship. Biophilia opens a path of expansive affirmation, well-being, and affiliative beauty. As I listen to the first bird of morning, I am aware of pleasure, joy, and the extraordinary beauty with which this message is delivered. Bringing *sustainability into the range of homeostatic effectiveness by* engaging *ancient pleasure/reward motivators* is the most viable path toward the *economics of resilience*. As organisms evolved to be warmed by the sun and cooled by evaporative transpiration, we require buildings that naturally maintain livable conditions when the next pandemic, heat wave, and power outage descends. Buildings that restoratively engage our senses and, thereby, our nervous systems in support of a resilient immune response. Urgently required is a paradigm shift towards designs that embrace *the duality of energy management optimization: quantitatively efficient designs* that foster climate-positive (carbon-negative) resilience of a building's carbon footprint (net-zero operational + low embodied + active sequestration) and *qualitatively efficient design* that fosters net-positive resilience of neuro-biological energy in support of public health. The qualitative can now be quantified in *body-nature-positive designs* that integrate biodiversity in *all* built environments. This cannot remain a luxury item available only to a select few. The solution to avoiding gentrification is to make this methodology commonplace as an essential aspect of our very humanity and the deeply intertwined twin goals of passive survivability and resilient public health. Evolutionary biology, biopsychology, neurobiology, chronobiology, sociobiology, and cognitive neuroscience provide comprehensive tools designers can use to deepen our work and curate well-being environments with clear public health-minded and science-informed intent. Equally important is remembering the wisdom of vernacular design, of working with patterns, spatial sequences, and proportions that are revered because they are neurologically compelling. Data suggest that places that restore and sustain us are the only value-adding investments both in terms of real estate value and the economic value of public health (*The Economics of Biophilia, 2023).* These two goals directly overlap. Only places that are perceptually fluid and cognitively legible permit emotional connection. As the pattern commonalities embedded in world heritage sites and other universally beloved buildings prove, we only sustain what sustains us.

In a time of heightened focus on what divides us, let us find meaning in serving what connects us, namely the innate biological traits we share with one another and with our non-human kin. Designing and retrofitting buildings to shelter and nourish birds, bees, and butterflies offers a simple roadmap toward built environments that also shelter and nourish human life. Only places designed in alignment with the biology of all of life can be considered relevant in the context of the 21st-century's dire challenges. All things considered, I consider *climate/eco-positive micro-habitat buildings* to be the only truly equitable building typology that fully meets this moment, future-proofing our cities by addressing the needs of *all* urban residents. Edges matter! *Ecotonal Building Envelopes (*EBEs) must supersede the dead and deadening façade language of so many current environments. As an industry, we must embrace nature as an aesthetic language and, along the way, revise our outdated notions of 'tidy' nature, allowing for life to be tangled and prolific. Akin to *green immune cells*, *all buildings, new and existing, must adapt to become climate-resilient, restorative infrastructure investments in public health*. Local ecology must become intrinsic to each EBE's design, *actively sequestering carbon*, *mitigating air, noise, and light pollution, naturally cooling interiors and surrounding neighborhoods, and fostering urban micro-habitat biodiversity* in symbiotic realignment with the biology of all urban lives. The hour is late, and it is time for implementation at scale, "high time to reconnect approaches and perspectives on development to the biosphere foundation" (Folke et al., 2016), to realign urban habitats with salutogenesis. Let's clothe our buildings in living, cooling "superterrestrial gardens" (Alexandri & Jones, 2008) and, while we're at it, let's infuse our ailing commercial districts (Badger, 2023) with new life. EBEs create effective thigmotaxis, especially at street level, literally growing an upgraded sidewalk experience that will add palatable microclimatic benefits and, therefore, enhanced real estate value to the entire building above. Once the twitter of birds moves in, we know people will follow.

In his project, *The Flying Gardens of Maybe,* artist Andrew Yang collected seeds from the guts of birds who died colliding with buildings and planted them in beautiful ceramic jars. He tended those seeds, honoring the life and labor of each bird while mourning "the vast ecology of interruption" that killed them all (Andrew Yang, *Flying Gardens of Maybe | New-empiricisms*, n.d.). Alternatively, imagine exhausted

birds arriving in now verdant cities filled with blooming vertical gardens and rooftop prairies that offer safe landing, nourishment, and nesting opportunities. Let us commit to tending Andrew Yang's beautiful *seeds of potential* until their young shoots can scale the heights of our buildings and, once again, reach the sky.

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