The Natural Environments Initiative:
Illustrative Review and Workshop Statement

HARVARD
SCHOOL OF PUBLIC HEALTH
Center for Health
and the Global Environment

Photo Credit Eric Chan

Acknowledgements

The Center for Health and the Global Environment (CHGE) at the Harvard School of Public Health was founded in 1996 to research and communicate connections between human health and our environment, and to accelerate the changes needed to ensure a healthy, sustainable, and prosperous future. In the ensuing years, radical environmental change coupled with exponential population growth has highlighted this interdependence and the role of cities as laboratories for progressive solutions. In October 2013, CHGE hosted a collaborative meeting in to explore the health benefits of nature and natural design cues with an eye towards emerging action areas in research, public policy, and planning. This paper evolved from the seminal discussions of the participants listed below and was shaped by the contributions of a several core authors. We collectively wish to acknowledge the generous support of the Radcliffe Institute for Advanced Studies at Harvard University; Ms. Karen Trevino, Chief, Natural Sounds and Night Skies Division, the United States National Park Service; Ms. Diana Allen, Chief, Healthy Parks Healthy People Program, the United States National Park Service; Mr. Christopher Zevitas, Senior Environmental Engineer, John A. Volpe National Transportation Systems Center; Drs. Korpela Kalevi, Qing Li, Alan Logan, Yoshifumi Miyazaki, and Yuko Tsunetsugu for making the world a smaller place; and finally the Center staff and leadership for their faith.

Co-Leaders

Dr. Jack Spengler Ph.D, Director, Center for Health and the Global Environment, and Akira Yamaguchi Professor of Health and Human Habitation at the Harvard School of Public Health

Julia Kane Africa MDesS, Program Leader, Nature, Health and the Built Environment Program, Center for Health and the Global Environment

Participants

Diana Allen MCRP, US National Park Service Healthy Parks Healthy People
Daniel Ibanez Doctoral Candidate, Harvard Graduate School of Design, USA
Korpela Kalevi Ph.D., University of Tampere, Finland
Laura Kubzansky Ph.D., Harvard School of Public Health, USA
Juyoung Lee Ph.D., Korean Forest Service, Korea
Qing Li M.D., Department of Hygiene and Public Health, Nippon Medical School, Japan
Alan Logan N.D., Invited Faculty, Continuing Medical Education, Harvard Medical School, USA
Eileen McNeely RNC., Ph.D., Harvard School of Public Health, USA
Richard Mitchell Ph.D., University of Glasgow, UK
Murray Mittleman M.D., Harvard School of Public Health, USA
Yoshifumi Miyazaki M.D., Chiba University, Japan
Elizabeth Nisbet Ph.D., Trent University, Canada
Catie Ryan, Terrapin Bright Green
Naomi Sachs, Doctoral Candidate, Texas A&M University College of Architecture, Center for Health Systems and Design, USA
Yuko Tsunetsugu Ph.D., Forestry and Forest Products Research Institute, Japan
Liisa Tyrväinen Ph.D., Finnish Forest Research Institute, Finland
Marc Weisskopf Ph.D., Harvard School of Public Health, USA

Nicole Bellisle, NEI Meeting Assistant & Photographer
Graphic Design by Erin Pellegrino M.Arch II, Harvard Graduate School of Design, USA

Citation information

The Natural Environments Initiative: Illustrative Review and Workshop Statement.
Africa, J., Logan, A., Mitchell, R., Korpela, K., Allen, D., Tyrväinen, L., Nisbet, E., Li, Q., Tsunetsugu, Y., Miyazaki, Y., Spengler, J.; on behalf of the NEI Working Group. Center for Health and the Global Environment at the Harvard School of Public Health, 2014.

Copyright and commercial use

This article is available to the general public without fee or other access control. Anyone may read this article or use it for personal or academic purposes with appropriate citation. No commercial use of any kind is permitted without permission. For reprint permission, contact us at www.chgeharvard.org/contact-us.

Copyright 2014 Presidents and Fellows of Harvard College, published by The Center for Health and the Global Environment.

HARVARD SCHOOL OF PUBLIC HEALTH | Center for Health and the Global Environment

Harvard School of Public Health
The Landmark Center
PO Box 15677
401 Park Drive, 4th Floor West, Suite 415
Boston, MA 02215
chge@hsph.harvard.edu

The Natural Environments Initiative:
Illustrative Review and Workshop Statement

ABSTRACT

This paper summarizes the discussions from the Natural Environments Initiative meeting hosted by the Center for Health and the Global Environment at the Harvard School of Public Health and the Harvard Radcliffe Institute for Advanced Studies in October 2013. It presents ongoing worldwide research on health benefits stemming from exposure to natural environments and design cues with particular attention applications in urban environments. This meeting generated a Workshop statement forged by the participants that affirms the health benefits of nature and presents the need for additional collaborative, transdisciplinary to refine salutogenic planning and design practices.

Workshop participants represented disciplinary and professional perspectives from medicine, landscape architecture, public heath, and forestry science rooted in the cultural, ecological and political realities of a dozen countries and five continents. When framing the benefits of nature, they considered health outcomes including mental health disorders, obesity, Type 2 diabetes, metabolic disorders, allergies, cardiovascular disease, and more. Many environmental factors (including those related to physical activity, residential planning, environmental contamination and severe weather attributed to climate change) mediate these health outcomes at local, regional and global levels. This paper provides an illustrative review that captures many relevant studies discussed during the workshop. Although not exhaustive, our review indicates that the available evidence is applicable to various populations and ecological settings, and broadly supports the association of improved health outcomes with exposure to natural environments.

TABLE OF CONTENTS:

INTRODUCTION	06
THE NATURAL ENVIRONMENTS INITIATIVE	07
EPIDEMIOLOGY—MENTAL HEALTH	08
EPIDEMIOLOGY—MORTALITY	09
GREEN SPACE IN SOCIOECONOMICALLY DISADVANTAGED COMMUNITIES	10
POPULATION STUDIES—IS IT MORE GREEN OR LESS GREY?	10
NATURAL ENVIRONMENTS—IN VIVO RESEARCH	13
GREEN EXERCISE	14
NATURAL ENVIRONMENTS—NEUROPHYSIOLOGY	16
NATURAL ENVIRONMENTS—IMAGERY	17
NON-VISUAL FACTORS	18
COMMUNITY GARDENS, VACANT LOTS	19
RELEVANCE TO URBAN LIFE AND SUSTAINABILITY	19
CONSENSUS	21
DISCUSSION AND FUTURE DIRECTIONS	21
REFERENCES	25

Photo Credit Stefan Georgi

Photo Credit Schub@ Photos

Introduction:

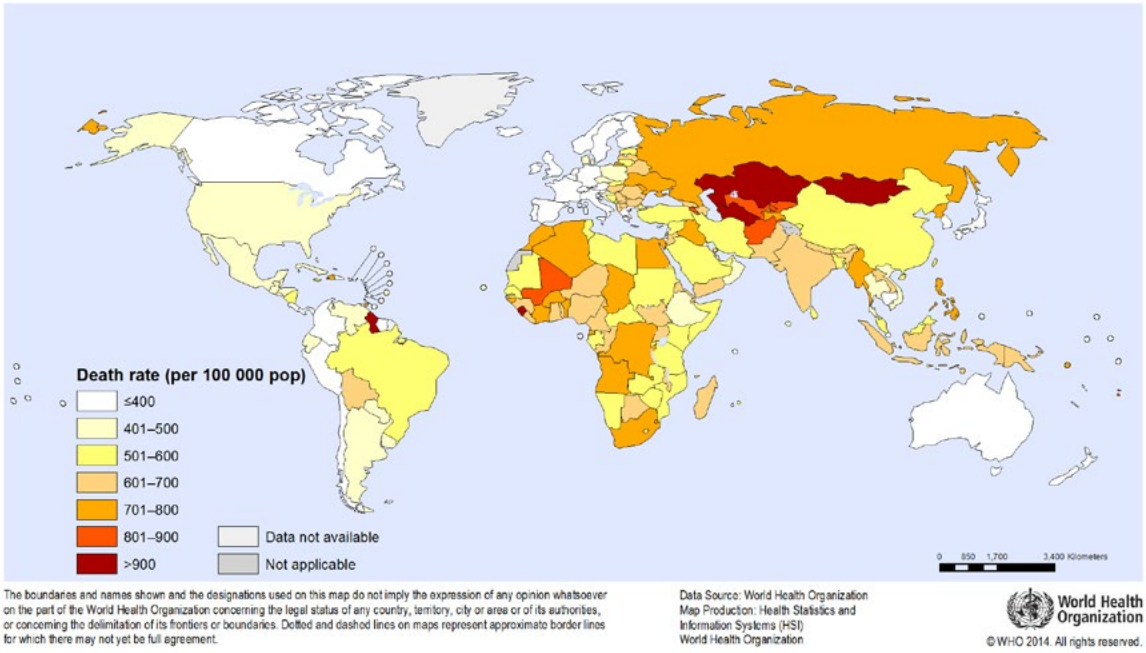
In our "Anthropocene era," human influences may be found in every flux and cycle of the planet's ecology and geochemistry, especially those stemming from rapid urbanization [1]. The growth in the size, density, and heterogeneity of cities throughout the world threatens the biodiversity and resilience of remaining rural and wild landscapes. Although urban environments can provide a vast array of benefits and opportunity—including education, healthcare and employment—this shift in land use practices that support expanding urban households and commercial operations raises complex questions and challenges for the future of life on earth [2,3].

Over half the world's population now resides in urban environments. Within the next several decades, 86% of the population of developed nations and 67% of developing nations may live in cities, with 1.35 billion new urban residents by 2030 [4,5]. In general, the health of urban populations, especially as measured by life expectancy and infant mortality, is often better in comparison to rural areas due to the availability of these resources. When coupled with the value of sustainable building and energy technologies, the future seems inevitably reliant on dense urban settlement patterns. Thoughtful urban growth may encourage more efficient distribution of resources and services, contribute to the protection of natural and cultural resources, and potentially relieve pressures on remaining arable and wild lands [6].

As cities grow, designers and planners will need to factor ecosystem services and the promotion of human health into their work. Generating and sustaining urban development that provides these supports remains an area of preliminary but very active investigation [3,7]. Conservationists increasingly recognize that they "must demonstrate how the fates of nature and of people are deeply intertwined—and then offer new strategies for promoting the health and prosperity of both" [8]; ideally, the city will be less a site of collision and conflict but rather one of intersection, integration, and reckoning.

Increasing and rapid urbanization is definitely not without its problems as increased density amplifies the ways in which urban areas may be harmful to health [9]. Urbanization is linked with chronic non-communicable diseases (NCDs) including mental health disorders, obesity, type 2 diabetes, metabolic syndrome, and cardiovascular disease [10-17]. Urbanization has also been associated with behavioral changes that contribute to NCDs, such as inadequate physical activity, poor sleep quality, and unhealthy dietary choices [11,17-19]. It is linked to troubling and often poorly-characterized exposures to environmental contaminants and pathogens, with socioeconomically disadvantaged communities often bearing unequal exposure burdens [20-22]. As best practices in the design and development of cities evolve, the environmental factors that support ecological, social, and personal resilience are under much-needed scrutiny insofar as they may help attenuate these outcomes [23-25]. Urban environments contain highly variable concentrations of natural amenities, from green roofs, rain gardens, and roadside abutments to pocket parks, forests, and bodies of water. The extent to which such natural environments might offset or mitigate NCD risk, promote health, and enhance quality of life [26.27] is the primary focus of this review.

Deaths due to noncommunicable diseases: age-standardized death rate (per 100,000 population)
Both sexes, 2012



Credit: World Health Organization, Global Health Observatory, 2014.

Understanding more about NCD pathways can shape city design considerations. For example, observed correlations between residential proximity to green space and lowered NCD risk [28] spur us to consider which attributes of the green space are potentially protective. NCDs often show significant overlap and bi-directionality of causation: depression is linked to subsequent risk of obesity and cardiovascular disease, and vice versa [29,30]. Lifestyle behaviors and environmental conditions (e.g., exercise; enhancing social support; safe, walkable streets) that attenuate risk or improve health outcomes are usually correlated with most NCDs [31-33].

The incidences of depression and anxiety, asthma and chronic obstructive pulmonary disease (COPD), diabetes, and coronary heart disease have been found to be significantly reduced for people living with more green space (10%, or more than the average) within a 1 km (0.6 mi) radius [34]. Further, the experience of nature has been associated with higher levels of physical activity, lower levels of mortality and chronic disease, improved self-esteem, and improved immune function [35-38]. Given that natural environments within urban settings support health through increased opportunities for exercise, stress-reduction, and social cohesion, they are a critical component in the design and development of future healthy, resilient cities [39,40].

The Natural Environments Initiative

With this framing in mind, the Center for Health and the Global Environment at the Harvard School of Public Health, with supplementary support from the U.S. National Park Service, hosted the 2013 Natural Environments Initiative workshop at the Radcliffe Institute for Advanced Studies in Cambridge, MA. An interdisciplinary and international meeting of scientists, scholars, and clinicians, the participants worked towards a contextual definition of nature and natural environments as a foundation for larger conversations about ecosystem services in cities, the design of salutogenic environments using natural design cues, and emerging trends in evidence-based public health research.

At the outset, we chose a broad definition of natural environments to capture regions relatively untouched by human activities, as well as those designed and maintained by humans for recreation and restoration in urban settings. The definition encompassed a range of ecological conditions, from sparse desert and savannah-like terrain to lush landscapes rich in trees, shrubs, bodies of water, and varying degrees of non-human animal life. Our concept of natural environments spans both green and blue space; it is inclusive of a variety of topographies,

features, and amenities that are not limited to a particular quality or type.

Our epidemiological inquiry considered spatial relationships as well as studies that attempted to isolate "active ingredients" from a range of sensorial, biochemical, and microbial features. Green space supports health through facilitating healthy lifestyle behaviors, including physical activity, recreation, gardening, and volunteerism. Exposure to nature may also deepen the social and political values of instilling conservation principles, altruism, and an environmental ethic. Any one of these factors can have a positive impact on human health; synergistically, they form a powerful bridge between the traditional conception of ecosystem services and public health.

Our review is not meta-analysis, a systematic review, nor an exhaustive compilation of the literature. We provide an illustrative synthesis that captures much of the research discussed during the workshop, and conclude with a consensus statement that affirms the potential for natural environments—wild, planned, or otherwise—to support human health in an age of dense cities and climate change. The Workshop Statement provides five action areas for the advancement of research and policy, and three key strategies for health promotion through natural environments. We acknowledge collectively that access to natural environments is only one of countless factors that foster a truly healthy, vibrant city. Deprived and at-risk communities are not exclusive to urban built environments, and some of the world's most violent political conflicts have occurred in non-urban "green space;" indeed, rural poverty is linked to all-cause mortality [41]. However, as planners, designers, and policymakers shepherd urban expansion and densification, it is important that they keep in mind a broad definition of ecosystem services that includes human health benefits [42,43].

Photo Credit Ralph Hockens

Epidemiology—Mental Health

Population-level studies provide a direct correlation between the existence of—as well as the perception of—green space in urban settings and improved mental health. Most of the studies discussed in this section have used objective measurements of vegetation and land-use characteristics to establish associations with various health-related endpoints. Residential proximity to green, vegetation-rich environments, rather than specific usage patterns such as frequency of park visits or enhanced physical activity, is the most common study format. For example, the Baltimore Ecosystem Study (n = 1,508) associated subjective assessments of the quality of the natural environments within urban neighborhoods with life satisfaction when measured at both the individual and neighborhood levels [44]. Likewise, a study from Adelaide, Australia, linked perceived neighborhood greenness with better mental health among 1,895 adults [45].

In a series of Dutch studies, researchers demonstrated associations between neighborhood greenness (typically within 1–3 km from home), self-reported general health, and a lowered risk of physician-assessed diseases—residents with only 10 % green space within 1 km of the residence had a 25% greater risk of depression and a 30% greater risk of anxiety disorders in contrast to residents in the highest (90%) residential green space bracket [34,46]. Similar results were reported by Danish researchers in a sample of over 11,200 adults. They found a 42% increase in self-reported stress levels among individuals living more than 1 km away from green space (including lakes and beaches), and those residing beyond the 1 km range had the worst scores on other dimensions of

general health, vitality, mental health, and bodily pain [47].

In New Zealand's largest and fastest growing city, Auckland, researchers compared neighborhood green space (divided into over 3000 small pockets) with the New Zealand Ministry of Health Tracker database for treatment of anxiety and mood disorders in the area (n=7552). Remarkably, every 1% increase in the proportion of useable or total green space was associated with a 4% lower rate of anxiety/mood disorder treatment. Viewed from a different angle, there was a 3% lower treatment rate for every 100 m decrease in distance to the nearest usable green space [48]. A recent population-level study from Wisconsin (n=2,479) compared mental health outcomes with an objectively determined vegetation index and percentage of neighborhood tree canopy coverage. Even after controlling for a wide variety of confounding factors, researchers associated with better mental health among urban or rural residents in areas with a high ratio of green space. Lower risk of depression was particularly strongly linked to neighborhood green space under all measurements—vegetation index, tree canopy, and an average of the two [49].

Researchers in Britain observed sustained mental health improvements among 594 individuals who relocated to areas with more green space; this effect continued for 3 years in the study sample, with yearly improvements in general mental health reported. These sustained mental health improvements were not observed in the years following a move to a less-green area [50]. Conversely, environmental degradation has been associated with poor mental health, including depression and a loss of sense of place [51].

Separate examinations of the British Household Panel Survey (BHPS) and land-use data in England found that coastal proximity (blue space) is also associated with better mental and general health even after controlling for the amount of green space [52]. In a sample of almost 260,000 Australians, a higher percentage of green space in neighborhoods (80% or more vs. 20% or less) was associated with a diminished likelihood of short sleep duration (less than 8 hours per night) [53]. Given the links between normal sleep duration, psychological wellbeing, and decreased risk of obesity [54-56], these findings reinforce access to green space as a health determinant at a broad population level, independent of physical activity, socioeconomic status, or current psychological distress.

Experimental research involving photographic scenes of nature (vs. "in vivo") with objective measurements helps corroborate the mental health value of green and blue space and provides some potential mechanisms of action. However, some population studies have also used stress physiology endpoints as health indicators. For example, studies involving socially disadvantaged adults in urban areas of Dundee, Scotland, reported healthier daytime salivary cortisol patterns and lower perceived stress in those residing in areas containing higher (>43%) green space [57,58]. Moreover, the larger of the two studies (n=106), reported gender differences in the relationship between stress and green space, with women living in proximity to low levels of green space reporting higher stress than co-resident men [58]. Current research suggests that green space may also influence maternal and child health, with positive or protective benefits for birth weight, risk of pre-term birth, and the potential for post-partum depression [59,60].

Epidemiology—Mortality

Over the last decade, the relationship between regional or neighborhood green space and mortality has been the subject of intense and increasingly sophisticated research efforts. Early research linked self-reported walkable green space in metropolitan Tokyo with a lowered risk of mortality in a 5-year cohort study involving over 2,200 older adults [61]. Separate research involving national Japanese data found that prefectures with the highest percentage of forest coverage had lower rates of lung, breast, and colon cancers, even after controlling for smoking and socioeconomic factors [62]. In a 1997 examination of each ward unit within the city of Shanghai, China, researchers reported a crude mortality rate that varied from 6.3 to 9.4 deaths per 1,000 population, depending on ward. Age-adjusted mortalities in this megacity were inversely related to higher proportion of neighborhood parks, gardens, and green areas [63].

North American research has also found links between green space and mortality. For example, a Canadian cohort

study involving 575,000 urban-dwelling adults, objective green space measurements, and follow-up mortality data spanning two decades, found that urban green space was associated with reduced overall non-accidental mortality, with the strongest association for reduced respiratory mortality [64]. In northwest Florida, researchers examined 5 years of stroke mortality data and compared it to objectively measured green space. They found that green space was associated with a lower risk of stroke mortality, while areas with low income and high air pollution were associated with the highest stroke mortality risk [65]. A relationship between residential green space and post-stroke mortality was also found when researchers evaluated a decade's worth of data from a major Boston-area teaching hospital. The mortality rates of patients living in the highest quartile of green space (measured by the satellite-derived Normalized Difference Vegetation Index) was 22% lower than that of patients in the lowest green space quartile. These differences were not explained by socioeconomic factors [66].

Researchers from the United Kingdom Office for National Statistics have also compared objective green space measurements to the national mortality records, noting an independent association between lower rates of circulatory disease and all-cause mortality for residents in the greenest areas. Controlling for socio-economic status revealed interesting correlations between green space and health inequalities. The combination of low-income and low residential-area green space was associated with cardiovascular mortality rates twice that of those living in more affluent areas. However, when low income was paired with high levels of residential-area urban green space, the delta between mortality rates found in affluent areas narrowed significantly [67]. Green space, therefore, appears to be an independent variable related to health inequalities.

Green Space in Socioeconomically Disadvantaged Communities

The findings discussed in the mental health and mortality sections of the workshop also fit into a variety of other metabolic health outcomes, especially those relevant to populations considered vulnerable by virtue of their social, economic, educational or political status. For example, decreased childhood obesity risk among low-income families is associated with higher street tree density (75th vs. 25th percentile) in urban environments [68]. There is also evidence that tree canopy cover and green spaces in urban areas, especially on public property, are associated with decreased crime and increased social cohesion [69,70], although we note that increased canopy density can diminish visibility and compromise perceptions of safety. In addition, research from the United Kingdom found that access to green space and lowered cardiovascular disease mortality is observed only in the most deprived communities—a finding that was not related to levels of physical activity [71].
Green space is also associated with decreased risk of type 2 diabetes, and although this was evident even after controlling for socio-economic and physical activity factors [72], the established links between depression and type 2 diabetes in deprived communities [73] might suggest a more potent value of green space in such neighborhoods. Disadvantaged communities are at a higher risk of exposure to air pollutants, and micro-urban heat island effects within densely built environments increase vulnerability to the effects of extreme heat [22,74,75]. Green space, or lack thereof, may influence the health effects of air quality and hot weather in these areas. Because many chronic medical conditions disproportionately affect those living in deprived communities [76,77], and if natural environments can help diminish the risk of common NCDs, it seems reasonable to postulate that such environments are especially important for vulnerable populations.

Population Studies—Is It More Green or Less Grey?

An absence of standardized research methodologies and evaluation strategies for qualitative analysis of green space characteristics complicate attempts to formulate exposure or dose-response models that are the common currency of applied public health. Challenges to interpretation stem from a variety of factors including reliance on self-reported health and perceptions of greenness, varied landscape characteristics in study settings, cross-sectional design, and differences in research population demographics. The working group notes that not all studies provide evidence in support of green space for improved mental health and decreased mortality [78-80]. The extent to which lowered NCD risk is mediated by usage patterns (exercise, socialization) rather than environmental features is an ongoing area of research [71, 81,82].

A number of studies have considered the question of whether regional differences in canopies and green space lessen exposure to airborne contaminants through physical removal, sequestration, or accelerated breakdown [83]. Leaf surface area of deciduous trees is correctly associated with seasonal decrements in particulate matter; the physical properties of the leaf surface (roughness, electrostatic charge, size) can influence removal and can be amplified in the humid microclimate created by a forest. Additionally, organic carbon in the soil can bind to airborne contaminants, effectively preventing re-suspension in the air or flushing in storm water. In the United States, trees were estimated to have removed 17.4 million tons of air pollutants in 2010 with an estimated 6.8 billion dollars in human health benefits [84]. Greenery may also serve as a surrogate marker for other health advantages enjoyed in some affluent, "leafy" neighborhoods. These advantages might include, but are not limited to, better access to healthcare, higher quality nutrition, better job security, more political power, and lower cumulative distress which, in turn, support healthy neuroendocrine function [85-87].

The opposite of green space might be referred to as "grey space," or built environments characterized by few natural features and an extensive loss of biodiversity. Areas with high concentrations of active or dormant industrial activity, fast-food outlets, and transport infrastructure are often mostly "grey" and are frequently associated with disadvantaged socioeconomic status [88,89]. Industrial activity itself is independently associated with psychological distress [88,90].

For example, researchers using urban development data from the Portuguese Ministry of Equipment, Planning, and Territorial Management and mental health questionnaires derived from community samples, found that residents in areas classified as industrial zones (higher frequency of chemical, textile, and/or mixed industrial activity) reported overall lower psychological health and well-being. In particular, as compared to those residing in areas with low industrial activity, these individuals reported decreased use of active coping strategies and less optimism [91]. The finding of less optimism is not trivial; higher levels of optimism have been specifically linked with healthy lifestyle behaviors [92], healthy blood lipids (greater high-density lipoprotein cholesterol [HDL-C] and lower triglycerides) [93]. The combination of low optimism and high anxiety (vs. high optimism and low anxiety) may increase vulnerability to the health-related consequences of airborne pollutants [94]. Among urban dwellers in Japan, for example, optimism is directly and independently associated with good mental health [95]. On the other hand, rates of anxiety and depression are especially high among those residing in proximity to industrial areas that contain higher levels of air pollution [91], while various environmental contaminants have been linked to anxiety, depression, and behavioral problems in human and experimental research [96-98].

Whereas increased grey space and overt environmental degradation in proximity to place of residence is associated with increased morbidity and mortality, biodiversity may be protective for health. Biodiversity refers to the variety of life—including species, the genes they contain, and ecosystems they form—that underlies much of what keeps people healthy, from adequate and clean water, to food, medicines, and freedom from infectious diseases [99].

For example, in North America the regional loss of over 100 million trees due to the destructive activity of the emerald ash borer (Agrilus planipennis, a non-native forest pest) has been associated with increased mortality related to cardiovascular and lower respiratory tract illnesses. Remarkably, the magnitude of this effect was greater in areas with higher household income [100], although whether this reflects higher proximal concentrations of trees or better overall health surveillance is hard to say. Australian studies have shown that environmental degradation in the form of dryland salinity is connected to depression, asthma, and heart disease. These findings are of interest because regional dryland salinity can be caused by the clearing of native vegetation and is associated with a loss of biodiversity. Much like the effects of the emerald ash borer, dryland salinity often results in very visible consequences, including the destruction of trees [101]. The extent to which urban green-space research findings at the population level are specifically related to untold markers of biodiversity, or the mere absence of grey zones (versus other more aesthetically pleasing and less-polluting built-structural zones), remains an open question.

A greater understanding of the psychological processes, habits, and traits that may mediate health outcomes in green vs. grey environments seems necessary. Few epidemiological studies provide information about the

residents' actual use of green space [102]. The differential benefits of green space at certain times in one's life course, as well as the role of gender differences and usage patterns, remains an active area of research [103]. Furthermore, repeated use of and attachments to green space may yield cumulative health benefits. Research suggests that at least some of the well-being effects derived from repeated use of natural spaces result from ongoing self-regulation where people select over time for natural settings that are more likely than others to provide resilience and personally restorative outcomes [104].

Population health is unequivocally supported by the preservation of biodiversity. Evolutionary processes favor biologically-active compounds, and intact ecologies yield a vast range of singular and synergistic compounds with distinctive effects; indeed, nearly every domain of human medicine relies on products derived from nature. Seventy-five percent of antibacterial compounds and 80% of anti-cancer agents have natural origins, and only a fraction of species on earth have been studied for their pharmacological potential, to date [99]. Technological advances have not displaced the reliance of agricultural productivity on the health of the surrounding ecology. We appropriate one-third to one-half of global ecosystem production for human consumption [105]. Marked population declines in organisms above and below ground that are vital to agriculture—notably including pollinators—threatens world food security, particularly for residents of the developing world and children. Engineering climate-adaptive crops, coupled with a resurgence of indigenous agricultural techniques that preserve biodiversity—such as intercropping and natural pest control—may yet offset some instability.

The role of zoonotic hosts in curtailing or augmenting the spread of infectious disease is debated. However, increased contact with zoonotic vectors through consumption of bush meat, habitat encroachment, and global transport of animal products is reshaping infectious disease ecology, given that 60% of human pathogens spend time in one or more non-human hosts. Hotter temperatures, combined with populations stressed by displacement, war, and resource shortages, suggest increased potential for infectious disease transmission and lowered resilience in the future [106]; loss of biodiversity further amplifies this trend [107]. One explanation is that pathogens are well adapted to ecological generalists that thrive during periods of disruption and displacement; another is that generalists have more "permissive" immune systems that carry, rather than devote, the metabolic resources needed to eradicate infectious organisms [108-110]. Whatever the explanation, resilience and capacity for adaption are closely related in this unstable climatic regime.

In the next 100 years, research suggests that climate change will surpass habitat loss as the leading cause of biodiversity loss, with extinction rates estimated to be somewhere between 10-1000 times higher than what is considered the "norm" [99]. There is unequivocal evidence that biodiversity loss lessens the capture of essential resources used in the production of biomass, decomposition, and nutrient cycling [111]. In addition to the loss of critical embedded ecosystem services and products mentioned above, the cultural, spiritual, and psychological loss that accompanies mass extinction is debilitating [112]. However, it is challenging to measure a direct correlation between ecological disruption and negative health outcomes because most industrialized societies draw on ecosystems far beyond where they live; those who have access can procure goods on regional or international markets, buffering local resource scarcity and potentially generating shortages or instability elsewhere [105]. While certain vulnerabilities to the degradation of local ecosystem services can be mitigated by infrastructure, people without access to markets that can defray the loss are particularly vulnerable. That being said, access to goods via the marketplace cannot replace personal, daily access to high quality natural environments and their potential health benefits (including security through local economic markets), rendering local loss of biodiversity a personal issue once again.

Public health is far too complex to be considered merely applied epidemiology [113], and as such, these findings can inform, but not determine, the location and characteristics of planned natural environments in urban settings. Conservation biologists, landscape architects and municipal planners, among others, are likely to determine future nodes of urban green space based on immediate dangers posed by climate change. The terms "ecological urbanism" and "ecological infrastructure" refer to planning principles that foreground the ecological context of the city over more traditional considerations [114,115]. Examples include the thoughtful use or creation of wetlands and barrier islands as storm surge barriers, urban forests to cool ambient temperatures and slow windspeeds, the "daylighting" of buried rivers or streams to improve drainage and habitat, and using plants

with strong root systems for erosion control or slope stabilization. The use of plants to mitigate or remediate environmental contamination forms a separate but related use of green space; with the exception of capped landfills, phytoremediation sites are not usually publicly accessible, but mature remediation ecosystems may provide many of the same visual or auxiliary ecosystem services attributed to parks. Taken together, the connection between health and green space is initially intuitive through the use of plants in engineered contexts to improve urban resilience, easing the way for a more holistic discussion of the potential for green space to improve individual psychosomatic health and resilience over time.

Although the modern use of ecological infrastructure is rooted in engineering and public safety, an evolving body of research documents historical trends in design and recommends general parameters for salutogenic spaces. Contemporary landscape preferences are thought to reflect innate landscape qualities that enhanced survival or dominance throughout human evolutionary history. Supporting theories include the Biophilia Hypothesis [116], the Savanna Hypothesis [117], the Habitat Theory and Prospect-Refuge theory [118], and the Preference Matrix [119].

A framework for "features and attributes of buildings linked to wellbeing needs and experiences in human-centric terms" was an early attempt to consolidate these theories into design practice [120]. More recently, the powerful observation that human-nature relationships tend to fall into three broad experiential categories—nature in the space, natural analogues, or nature of the space [121] —forms the backbone for 14 patterns identified as biophilic design guidelines. By combining exposure to biota with natural materials and nature-influenced design strategies, biophilic design adds an additional dimension of salutogenic potential to existing ecological infrastructure in urban contexts. Sophisticated measurements and technological advances are helping to guide design strategies, including the mitigation of the previously-mentioned urban heat island effects [122].

When evaluating potential applications of natural environments in public health practice, we must examine the ratio of reward to risk, the specificity and consistency of the findings, the clarity of the dose-response curve, and the concordance with what is already known from other branches of medical and scientific literature. It is worth noting that the health benefits of nature can be found in wild and designed landscapes as well as, in some cases, the mimesis offered by built environment settings that offer natural design cues. We needn't confine ourselves to the untouched Edens of yesteryear and, indeed, must increasingly value nature in the context of escalating environmental, social, and political demands. The answers to these and other questions, particularly as they pertain to causal frameworks and the progression of illness, require much more research. However, support from experimental data favors green space as a stand-alone public health variable and is very much strengthened by a variety of in vivo and experimental studies presented below.

Photo Credit Michael Seljos

Natural Environments—In Vivo Research

Studies that compare activities such as walking in natural environments versus conducting the same activity in the built environment have helped researchers consider how exposure affects acute and chronic markers

of health. Many factors, including the specific pathophysiology or outcome under study, gender, and baseline health status of the participant influence experimental methodology. Broadly speaking, relevant indicators of personal health can be divided into acute, chronic, behavioral and cognitive categories.

Acute physiological markers can include pulse rate, blood pressure, skin conductance, salivary cortisol, temperature, and other factors which demonstrate nervous system arousal [123]; chronic physiological markers can include changes in urinary metabolites, immune defense and inflammatory markers, and other indicators in blood chemistry [124]; behavioral markers can include prosocial behavior [125] or self-regulation [126]; emotional markers can include self-rated evaluations of mood, including depression and anxiety; and cognitive markers include performance on work tasks, working memory capacity [127], capacity to pay attention, accuracy, efficiency, and reaction time [128-131].

The growing use of pre- and post-objective measurements of physiology and utilization of validated instruments of neuropsychological relevance continue to strengthen the quality of research available in this field. For example, researchers induce cognitive fatigue with mentally challenging tasks designed to place demands on sustained attention. Immediately following this intense cognitive effort, the subjects walk for varying intervals (typically 30-60 minutes) in a vegetation-rich park or on city streets and, at the conclusion of the walk, neuropsychological tests are repeated. Using this general design, researchers have reported more significant cognitive benefits post-nature walk in healthy adults [132,133], children with attention deficit [134], and adults with depression [127]. This cognitive restoration may occur without changes in emotional state per se, suggesting that the cognitive benefits are not merely the result of acute positive mental outlook [127].

Research involving 51 university students has also showed that when subjects are randomly queried (via pager at various times between 10:00 AM - 10:00 PM) about current activities and vitality, nature was a mediator of subjective vitality [135]. Middle-aged adults exhibited improvements in restoration, mood, and vitality when walking in an urban park or woodland, versus city center, after their work day in Helsinki, Finland [136]. Still, the extent to which physical activity (see the "Green Exercise" section within this paper) and mental outlook are intertwined with natural environments—and outcomes such as creativity and vitality—requires further study.

A large volume of research on the Japanese practice of shinrin-yoku (translated as "forest bathing" or "taking in the forest") examines the use of forests as therapeutic environments. Reviews and original research on the subject through 2010 captured nine studies involving field work evaluating forest walking or comfortably seated viewing and contemplation of the forest, versus an urban built environment. The forest experience improved subjective mood state, and resulted in a variety of physiological changes including lowered cortisol levels, reduced sympathetic tone, improved natural killer cell count and activity, lowered pulse rate and blood pressure, and improved heart rate variability [137,138]. More recent studies, including those from China and Korea, have documented similar improvements in subjective mood and endpoints such as stress hormones, oxidative stress, systemic inflammation, and blood pressure [139-143]. The major limitation of existing shinrin-yoku and forest therapy studies is small sample size. Although the field work involving multiple forests can be combined for a more robust effect, study populations ranging from 10-12 subjects per forest [137,138] do not allow us to make inferences at the population level with certainty. In addition, the bulk of the research has involved healthy, young, predominately male, student volunteers. In addition to statistically significant sample sizes, more research is required to profile representative population samples or specific subgroups that might benefit most from forest exposures.

Factors such as age, health status, psychological characteristics, fitness, and education level likely influence the effect of forest exposure. The influence of familial, regional, and national cultural background remain largely unexplored, as does the effect of environmental education across the life course. Specific attributes of urban forests, including tree type, canopy density, and biodiversity are also influential; the parameters of more- versus less-therapeutic forest environments will influence the planning and maintenance of future urban parks. Researchers are turning their attention to more specific parameters such as how seasonal changes in forests might influence outcomes. For example, the benefits of walking in an urban park in metropolitan Chiba, Japan, have been documented in winter, despite the loss of significant amounts of foliage [144].

In Japan, researchers have identified a heterogeneous, volatile class of plant-derived compounds (called "phytoncides") as physiologically active and potentially pivotal in the experience of restorative environments. Phytoncides are released by plants as defensive and signaling compounds. As such, they are ubiquitous in low levels in forests but higher under certain conditions. Forests at the height of metabolic activity (generally summer), with significant biodiversity, with aromatic trees (pine, cypress, etc.), and stress (climate change-related shifts in precipitation, temperature, and pest activity) have higher levels of phytoncides, particularly in the morning [145].

Although identifying the salient environmental and landscape features that signal clinically effective environments is important, many confounding factors influence each individual's "dosage." Statistically significant, population-level studies are critical to understanding how to form broad, clinically useful recommendations. In a natural world increasingly marked by uncertainty and radical ecological change, shifts in the prevalence of infectious disease, precipitation regimens, temperature ranges, and other ambient atmospheric conditions attributed to climate change shatter long held perceptions of timelessness and stability in our natural environment. Is an ocean view restful from an eroding shoreline? Is a forest walk soothing amid new and virulent insect-borne diseases? For whatever changes we may struggle with, the plants must struggle more; those that can adapt to new climatic circumstances may do so in unpredictable ways that affect their nutritional, toxicological, and aesthetic characteristics [146-149]. Given this information, one must hope that the beneficial effects of green spaces are not solely reliant on a spectrum of phytometabolites, which vary in response to ambient environmental conditions.

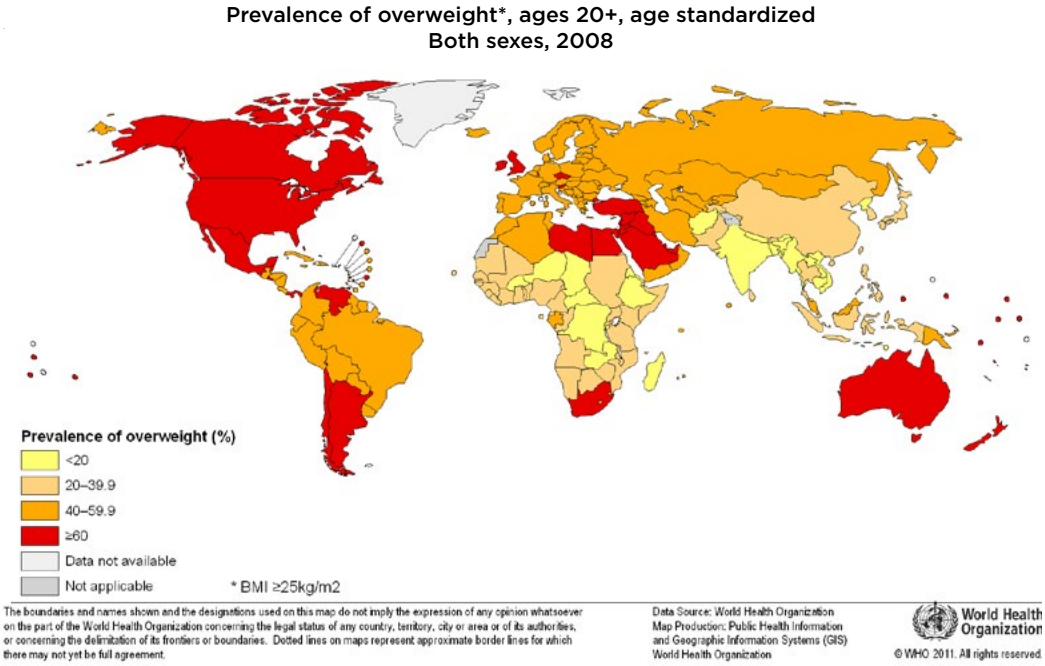
Photo Credit Francois Schnell

Green Exercise

A great deal of research has explored the extent to which residence in proximity to natural areas might encourage physical activity rates. Nature experience has been associated with higher levels of physical activity, lower levels of mortality and chronic disease, improved self-esteem, and improved immune function [35-38]. It is clear that many people use natural areas to be physically active, and it is certain that physical activity carries benefits for mental health [150,151]. It is not clear, however, whether the mere presence of a natural environment is a causal factor in perceived regularity of or benefits from physical activity [152-155]. For example, people tend to exercise for longer periods and more vigorously when outdoors. Outdoor walking has been found to be associated with higher levels of enjoyment and intention for future outdoor walking, when compared to indoor walking [35,156]. There may also be cultural contributions or personal affinities toward nature that may increase the likelihood of physical activity in natural environments that are in close proximity to a residence [157,158].

Physical activity conducted in natural environments may have some "added-value" properties [35]. For example, data from the 2008 Scottish Health Survey shows an independent relationship between regular use of natural environments and a significantly lower risk of poor mental health [102]. Group walks in green settings and natural environments have also been shown to be associated with less perceived stress and less negative effect versus urban built environments [159]. There is also evidence indicating that, once initiated, exercise conducted in outdoor settings or green space (versus indoors) may enhance mood and self-esteem, as well as motivation to maintain a regular routine of physical activity [160-162]. For example, outdoor walkers maintain their routines

by focusing on positive health outcomes and using attractive natural settings [163]. Finally, it is interesting to note that the quantity of green space within the vicinity of outdoor competition sites has been associated with physical performance outcomes [164].



Credit: World Health Organization, Global Health Observatory, 2014.

Natural Environments—Neurophysiology

Researchers using electroencephalography (EEG) have reported higher alpha wave activity when viewing scenes of natural environments, suggesting a state of relaxed wakefulness and lowered anxiety [165-167]. While it is difficult to utilize bulky neuroimaging techniques in field settings, researchers have recently made some efforts to examine neurophysiology in outdoor environments. For example, a recent study used wireless real-time EEG measurements during a 25-minute outdoor walk. The walk began in an urban shopping district, passed through a vegetation-rich urban park, and then concluded in a commercial district. The results of EEG measurements suggested less arousal and alertness while transitioning through the urban green space [168]. This finding is consistent with separate Japanese research during a forest therapy study. Investigators used near-infrared time-resolved spectroscopy (NITRS) —a device that measures oxygen use in the brain via the reflection of near infrared light from red blood cells—and reported that 20 minutes of comfortably viewing an outdoor forest setting, versus viewing an urban control setting, changed cerebral blood flow in ways that typify a state of relaxation [169].

Research on environmental preferences has shown that humans consistently prefer scenes of natural environments versus urban built environments, even when the images are presented as rapidly as a fraction of a second [170]. Moreover, there is evidence that seeing urban and natural environments that are associated with low- and high-restorative potential, respectively, triggers rapid and automatic affective responses within milliseconds. These responses influence the processing of vocal or facial expressions signaling emotions like anger, disgust and happiness [171,172]. Expressions of happiness were recognized after the presentation of restorative nature scenes faster than after the presentation of less restorative urban scenes and, conversely, the expressions of anger were recognized faster after the urban nature scenes.

A number of functional magnetic resonance imaging (fMRI) studies have evaluated brain activation patterns while images of urban built environments, versus natural environments, are presented [173-175]. Unlike the urban scenes, images of the natural environment were associated with increased activity in brain regions associated with positive emotion. Urban scenes resulted in enhanced activity in the amygdala, a region that handles threat. Separate research found that compared to rural dwellers, otherwise healthy urban residents have increased activity in the amygdala while performing challenging tasks in conjunction with researcher-induced perceived

social stress [176]. The extent to which the environmental colors of blue and green mediate brain activation in areas associated with emotional response is an active area of investigation [177]. In addition, investigations involving adults from remote rural regions have shown that, compared to urban residents, they are far less distracted by irrelevant information during cognitive tasks [178]. The results of these studies suggest that when tonic alertness swings past its optimal operating point, as it seems to do in high-demand urban environments, the cognitive toll is a reduced capacity for selective attention [179]. This cognitive toll, as we will discuss below, is of potential relevance to impulsivity and helping behavior in the context of urban life.

Photo Credit Madame Ming

Natural Environments—Imagery

Functional brain imaging studies capture the visual responses to an environmental scene, a common variable in laboratory experiments. Indeed, the bulk of the experimental studies on natural environments have focused on the visual system. Immediately after humans are subjected to a laboratory stressor, markers of stress physiology—electromyography (EMG), skin conductance (SC) and pulse transit time (PTT)—support subjective reports of a more rapid return to normalcy when viewing scenes of natural versus urban built environments [123]. Electrocardiogram (ECG) research has also shown that when adult volunteers view scenes of nature versus urban built environments for 10 minutes prior to a mental stressor, there is enhanced heart rate variability and more dominant parasympathetic activity [180].

Laboratory studies also provide support to the cognitive restoration effects noted after outdoor walks in nature. Using similar techniques to the outdoor study methods, researchers induce mental fatigue in volunteers by having them complete cognitively demanding tasks. Subsequently, the volunteers are divided into groups that view images of the urban built or natural environments for a brief period before returning to complex cognitive tasks. Compared to imagery of the built environment, memory recall and other aspects of cognitive performance were better after viewing scenes of natural environments [129,181,182].

Other studies have examined endpoints related to the visual experience of actual nature scenes through windows. As found in an oft-cited study involving 11 years of cholesytectomy data derived from a Pennsylvania hospital, those who were in recovery rooms with a view to a small forest (versus a room with similar light and a view to other buildings) had shorter hospital stays, used less potent analgesics, and had fewer post-surgical complaints [183].

In a Michigan study involving over 100 public high schools, the view from the classroom and main dining areas were evaluated for the quantity and quality of green elements such as trees, shrubs, groomed lawns, and athletic fields. Controlling for socio-economic variables, class size, age of the school facilities, and other factors, the results demonstrated that the view to vegetation was associated with better performance on standardized academic tests. The complexity of the view is significant: Views to trees and shrubbery, as opposed to lawns and groomed

fields, were specifically associated with higher graduation rates and future plans for advanced studies [184]. An even larger study involving 905 public schools in Massachusetts measured surrounding greenness of each school via satellite imagery and examined standardized math and English scores reported to the Massachusetts Department of Education between 2006 and 2012. Total greenness of the school area was associated with school-wide academic performance in both subjects, even after controlling for socioeconomic factors and urban residency [185].

Non-Visual Factors

There is far more to the natural environment than that which might be absorbed by the visual system. Research suggests that phytochemicals (phytoncides) secreted by trees and plants might have a beneficial influence on the immune and central nervous systems [186-188]. Natural environments, especially coastal, forest, and vegetation-rich locations, also have higher levels of negative ions within the outdoor air sampled in built urban settings [140,189,190]. Although there are mixed results on the influence of negative ion generators in clinical studies related to asthma and lung function [191], some research suggests value in the treatment of depression [192,193]. Moreover, natural environments contain soundscapes with layered complexity (as found in birdsongs or the fractal patterns of a babbling brook) or a near-silence that might have a beneficial effect on stress reduction and cognitive restoration [194-196].

Touch and texture are also important components of the sensory experience. A study whose participants had shielded eyes revealed that the touch of a leaf versus synthetic materials and a resin composite leaf produced cerebral blood flow changes indicative of relaxation [197]. Separate research involving 119 adults found that those who were working hands-on with potted plants (as opposed to setting up pots with soil without handling living plants) experienced less self-reported fatigue and higher EEG alpha wave activity, indicating relaxed wakefulness and decreased muscular tension [198].

Exposure to microscopic organisms that cannot be seen or directly experienced by the somatosensory system is a powerful determinant of human health. Potentially beneficial microbes—lactic acid bacteria in general, and microbial genera such as lactobacillus and bifidobacterium in particular—are most commonly associated with fermented dairy products and probiotics. However, these bacteria are ubiquitous in the natural environment, commonly found in soils, leaves, and edible plants [199-201]. Over a decade ago it was proposed that, due to the way lactic acid bacteria influence immune and nervous system function, they could be used, intentionally, for unexplained medical conditions where depression is common [202]. Emerging research, including studies in humans, has supported this hypothesis, suggesting that gut-to-brain communication between diverse non-pathogenic microbes may influence depression, fatigue, and cognition [203].

Some of the lactobacillus strains purported to promote brain health can be found in North American garden soil, as discovered by scientists over a century ago [204]. A 2013 animal study showed that Mycobacterium vaccae, a non-pathogenic microbe commonly found in soil, promotes learning and diminishes anxiety-like behavior in animals [205]. Intriguing research has linked biodiversity of vegetation type around one's home with increased biodiversity of microbes on the skin, and in turn, a decreased risk of atopy [206]. Such research is relevant to developed urban environments that enjoy good sanitation, an abundance of sanitary products, high antimicrobial use, and lower opportunity for incidental contact with non-pathogenic microbes typical of outdoor occupations and leisure activities in rural areas. Compared to developing nations, rates of allergies, asthma, and autoimmune conditions are far higher in sanitary developed nations [207].

There are many potential factors at play in these findings. The so-called "hygiene hypothesis" suggests that a withdrawal from a traditional lifestyle toward a more sanitized "antimicrobial" environment—resulting in alterations to normal immune development and reactivity—may be making a significant contribution to risk [208]. Much like the epidemiological research on green space as it relates to grey space, it is unclear at this point if the overall health benefits of non-visual aspects of nature might stand alone, or if they are a surrogate marker for less of the environmental characteristics that are known to be detrimental to health, like air pollution

and noise. Until the evidence base expands, the relevance of such research to public health remains uncertain. However, major questions concerning these interactions as they relate to green and blue space warrant further research.

Photo Credit Pantelis Petrou

Community Gardens, Vacant Lots

Gardens may be one of the most effective hands-on ways to ensure aspects of nature can be experienced in the urban environment [209]. Tending urban green space—from gardens to byways—is associated with healthier dietary practices, lower body mass index, improved mental health, and increased social engagement [210-212]. Gardening, wherever it may be practiced, provides the opportunity for moderate-intensity physical activity [213,214]; it is also capable of inducing relaxation [215] and improving mood [216], life satisfaction, optimism [217], and self-esteem [218]. Gardening may provide adjunct therapy for standard treatment of depression [219,220] and posttraumatic stress disorder [221]. Meanwhile, the conversion of urban vacant lots to green lots has been connected to crime reduction and improved community health outcomes [222,223].

Although it is a poetic truism to say that a garden can live on in one's heart forever, experience with gardening programs in youth is associated with pro-environmental attitudes later in life [224]. Preliminary studies also suggest that gardening experience in school settings increases positive environmental attitudes [225] and subsequently increases the value placed on local foods, including the environment in which produce is grown [226]. This finding is consistent with studies that indicate early experiences in nature influence subsequent environmental attitudes and concern for stewardship and sustainability [227-230]. Moreover, in an age where early-grade educators are placing a priority on science, technology, engineering, and math (STEM) [231], it is worth noting that academic gardening programs have been associated with improved science and math scores and an enhanced ability to work in groups [232-234]. Growing produce in contaminated urban environments, however, may increase exposure through soil contact, inhalation, and ingestion, so research recommends the use of gloves, clean topsoil in raised beds, and thorough washing of produce to limit ingestion of soil particles [235,236].

Relevance to Urban Life and Sustainability

The studies discussed above indicate that green space plays an important role in supporting urban health and sustainability but do not yet allow us to discern specific design features that lead to statistically significant positive health outcomes. The term "ecosystem services" must necessarily expand to include the range of health benefits attributed to nature which, to date, include engineered outcomes (remediation or sequestration of wastes to improve environmental quality) as well as more social or aesthetic benefits. The overall cognitive load within an urban environment, perceived competition for resources, and even physical aspects of the built environment that are outside of conscious awareness may magnify delay discounting—the tendency to choose smaller, more

immediate benefits over longer-term substantial benefits. Alarmingly, future health gains are highly discounted by respondents in experimental studies involving immediate versus future rewards [237]. Such research is of relevance to urbanicity, defined as the impact of living in an urban environment at a given point in time, wherein there are conditions either particular to that area or that occur to a much higher degree than would be present in nonurban areas [238]. Put simply, elements of grey space vs. natural environments may have, in the here-and-now, divergent influences on attitudinal and behavioral variables and lifestyle choices related to subsequent personal, communal, and even planetary health.

Future discounting may influence lifestyle choices and environmental ethicism. In three studies—where two took place in a laboratory and the third was held in an outdoor field setting—researchers found that viewing scenes of nature or being in urban green space, versus being in the control scenes of the urban built environment, was associated with significant reductions in discounting the future [239]. Walking outdoors facilitates "nature relatedness," or a sense of self, framed within the context of the natural environment; this psychological framework lays the groundwork for lifelong environmental advocacy [240]. Higher scores on nature relatedness and other scales, such as "connectedness with nature" and "nature connectivity" are significantly correlated with psychological well-being, meaningfulness in life, and overall vitality [241-243]. Although studies have shown that experiences in natural environments can increase short-term changes in nature connectivity, what is missing, for the moment, is research showing that relatively brief or repeated urban nature experiences can influence long-term attitudinal shifts [244].

Natural areas are still not considered a necessity, particularly in urban areas where the competition for land is intense, land values are high, or funds for maintenance are low. Compact city policies have led to even greater pressure on urban green areas. Therefore, the public health benefits of forests must be better understood and more effectively communicated. Although there is increasing knowledge of the health benefits of green areas, estimates of their economic value through health care savings is called for. There are only few studies looking at appropriate methodologies and aiming at valuing the health effects of green areas. Most clear health benefits can be linked to increased physical exercise. One recent study estimated that if 1% of the population within the United Kingdom had adequate physical exercise as a result of proximal green space, cost savings would result from averting 1,063 premature deaths and decrements in life-style related diseases, including 14,500 cardiovascular disease cases, 445 strokes, and 100 cases of colon cancer [245]. However, despite the suggestive evidence that reconnecting people with nature may improve human and environmental health, the longitudinal studies on nature contact are mostly correlational and thus direction or causality are still unknown.

Biodiversity may play a pivotal role in supporting the salutogenic environments. Although there are exceptions with certain species, urbanization decreases population health and works against biodiversity [246]. Biophilic design strategies privilege nature and natural design cues but do not necessarily support biodiversity; in contrast, projects like the Biophilic Cities Network [247] address our innate need for nature at multiple scales with explicit acknowledgement of the psychological benefits of perceived—and proximal—biodiversity [248,249]. The Living Building Challenge [250] and Sustainable Sites Initiative [251] offer other compelling efforts by different professional bodies to assess the integration of local and regional ecology with the urban form and metabolism.

As global urbanization continues and emerging research connects climate change and biodiversity loss with detrimental health effects [252,253], it becomes imperative to consider biodiversity—comprised of species that make green space "green" as well as the invisible microbes that live upon them—as part of the green and blue space research context. It seems possible, therefore, to bring the objectives of environmental health, public health, mental health, and biodiversity into alignment. With a more thorough understanding of such links, we can determine best paths to take in the design of our future cities.

Photo Credit Adam Balch

Consensus

Although we are just beginning to understand some of the variables and characteristics that contribute to salutogenic natural environments, enough is known presently to crystallize the Natural Environments Initiative working group's affirmation of the multifaceted benefits that natural environments provide for psychosomatic health.

Participants affirmed the need for further evidence-based research coupled with greater consistency of research methodology and evaluation. In the meantime, in anticipation of the additional 1.35 billion urban residents expected just over a decade from now, the available evidence suggests that improving access to and utilization of urban nature for recreation and restoration should be a public health priority.

Physicians, public health experts, social and behavioral scientists, urban planners, naturalists, and ecologists must synergistically envision the sustainable, equitable, and salutogenic parks and natural environments of the future. Our workshop generated a position statement that affirms the potential of natural environments to contextualize our shared "human condition," transcend psychosomatic stressors, mitigate environmental contaminants, and buffer the ill effects of climate change. The broad contribution of scientists, scholars, students, and practitioners should be welcomed in a collective effort toward refining the salutogenic lens, one more capable of envisioning urban ecosystem services.

Discussion and Future Directions

Much of the research to date has established links between natural environments and/or elements of nature with overall well-being and mental health. We would argue that the research focus on psychological well-being is very appropriate when considering that urbanization, biodiversity loss, and increased global awareness of illness are occurring in tandem. The "No Health without Mental Health" mandate used by the World Health Organization and many of the leading psychiatric organizations [254] is an evidence-based imperative to design environments that are supportive—rather than merely protective—of public health and well-being. Volumes of international research demonstrate a bi-directional relationship between mental health disorders and the risk of a variety of chronic conditions, most notably type 2 diabetes and cardiovascular and gastrointestinal diseases and disorders [255-260]. Mental health encompasses a continuum that includes quality of life—and culturally situated "happiness"—to serious diagnoses within the American Psychiatric Association's Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-V); sub-clinical depression has drawn increased research attention in the context of diminished quality of life [261]. Mental health, viewed broadly and either in positive or negative terms, is an "upstream" factor that contributes in beneficial or detrimental ways to disease risk; from this standpoint, the contribution of natural environments to sound mental health at personal and community levels takes on new urgency.

Beyond urbanization, there is another context in which discussions of natural environments and health are taking place: changes to daily activity via marked increases in screen and device-driven information consumption. Much like certain aspects of urbanization, there are many advantages to rapid advances in information technology, especially in the context of public health, wherein critically important information can be disseminated. However, the differential contribution of screen time quantity and quality to health is difficult to resolve. Canadian research conducted over the last decade indicates that adults and children are spending less time outdoors and more time indoors. Is this a broad trend in developed nations, and, if so, what are we doing with the additional time spent indoors [262]? Modern technological gadgets and the draw of screen-based media may be contributing to a displacement of nature-based recreation [263-265]. Since causation has not been proven, these indicators require further investigation.

Research does show, however, that in neighborhoods where walkability is low, screen time is higher [266,267]. (Walkability is determined not only by available paths for walking and cycling, but also by aspects of safety, traffic, residential density, aesthetics and neighbourhood satisfaction.) Children residing in urban environments [268] and socioeconomically disadvantaged neighborhoods [269] have higher daily screen time than affluent counterparts. Excess screen-based media consumption and so-called "techno-stress" have recently been linked with poor psychological health [270-277], and given the research discussed above on the psychological benefits associated with outdoor natural environments, it would be valuable to determine possible interactions. Put simply, it seems fair to question a possible synergistic relationship on psychological well-being between less time spent in natural environments and more screen time.

Moreover, there have been well-documented generational increases in depression, anxiety, and behavioral disorders in North America; these have been occurring in concert with generational increases in narcissism, and marked declines in empathy, concern for others, and perspective-taking. The shifts have been most noticeable over the last 10-15 years [278-280]. Given the research cited above on natural environments, elements of nature and altruism, and concern for others, we wonder to what extent screen media consumption may be acting in concert with less contact with nature. On the other hand, it is entirely possible that the specific application of technological advances, including those delivered via a smartphone, might encourage interaction with nature and greater knowledge of local biodiversity. Research devoted to possible connectedness-enhancing technology and social media is a worthwhile endeavor, as would be promising low-tech education and citizen science ventures.

Strengthening the quality of evidence used by clinicians, planners, landscape architects, and others is critical. Pressing areas of inquiry include the ways in which natural environment-related outcomes are influenced by current physical and mental health status, age, gender, socioeconomic status, personality, landscape and structural design, urbanicity, media use, and cultural variables, among others. Most of the evidence to date has emerged from highly developed nations, leaving major knowledge gaps concerning the role of natural environments and urban green spaces in Africa, South America, and Eastern Europe [281]. Beyond green and blue space quantity, we need to further understand what defines quality as it relates to health [282-284]. Will our growing understanding allow us to design green spaces for specific conditions or purported psychosomatic effects? Risks in natural environments [285-287]—whether from excess ultraviolet radiation, classical dangers associated with human-wildlife conflict, allergens, insect-borne diseases, or emergent concerns related to safety, security, and environmental contamination—are barriers to be heeded or negotiated when prescribing the outdoors.

The existing research, despite its many limitations, does suggest that natural environments and access to biodiversity are indeed essential to public health, especially in urban settings. The available evidence also suggests that there is, at present, a lack of equity in such access. Low-income, disadvantaged neighborhoods may not only have less urban green space overall and less biodiversity of plant and animal life—additionally, residents within such areas often report less frequent local park use and recreational walking [155,288-290]. Further research will improve our grasp of the functional attributes and design parameters that comprise healthful natural environments; if it is possible to define a "minimum dose" that is protective of human health, then ideally all citizens should be given equitable access to supportive green space. Moreover, as researchers fill knowledge

gaps concerning the ways in which cities can become resilient and sustainable, it is abundantly clear that the process will require reinvestment in derelict or peripheral areas that have been traditionally marginalized [7]. Put simply, the provisioning of ecosystem services, matters of environmental justice, and access to urban green space are overlapping discussions [291,292].

The last word is far from written. Current efforts to consider policy processes are highly dependent upon quality of research. Larger studies, longitudinal studies, and replication in various settings and populations are essential to furthering our understanding of the value of natural environments in human health promotion. Existing research needs to be expanded upon. However, the problems associated with the isolation and heterogeneity of the current body of research will not be solved by simply applying a larger n= to the equation. In order to advance this area of research, transdisciplinary, cross-cultural collaboration and translation will be necessary.

Ongoing global initiatives include the International Union of Forest Research Organizations (IUFRO), which initiated a special task force on Forests and Human Health in 2011, an effort that connects forestry and health science professionals [293]. The Cooperation on Health and Biodiversity (COHAB) initiative links biodiversity with human health and well-being within the larger framework of the United Nation's Millennium Development Goals [294]. The International Union for Conservation of Nature (IUCN) established the Healthy Parks Healthy People (HPHP) Task Force in 2010 to provide guidance to IUCN, national policymakers, and practitioners with regard to the relationships between human health, community well-being, economic prosperity (for example, nature-based tourism), ecosystem services, and protected areas [295]. It also seeks to establish alliances with government and nongovernmental sectors to advance the development of research that links societies and economies with parks to demonstrate the health benefits of nature. In the United States, the U.S. National Park Service, the U.S. Forestry Service, the Centers for Disease Control and Pan American Health Organization have joint and several fledgling initiatives to incorporate the Health Parks Healthy People agenda [296]. Within the European Union, COST (Cooperation in Science and Technology) Action E39 (Forests, Trees, Human Health, and Well-being) works to summarize knowledge about the contribution of natural places to human health and well-being in Europe [297]. All of these efforts bridge professional, disciplinary, and political differences to support the integration of natural environments as part of a larger healthcare strategy.

Robust dialogues will improve theoretical frameworks, research methodology, and associated applications in the public and private sector. The provision of easily accessible, high quality, nature-based health products and services could potentially reduce healthcare expenditures; although there are promising examples of implementing research results in practice, the clinical benefits and financial implications of this strategy need refinement. In the immediate future, more research supporting the physiological and psychological health benefits of exposure to nature is needed for adoption in policy and practice as well as accurate monetization. For example, the influence of landscape characteristics including season, relative biodiversity, and vigor on the therapeutic and restorative benefits of forests is under increasing scrutiny. Cultural, individual, and social differences may mediate the experience of health benefits of green environments in ways that are not fully understood. The long-term health benefits of exposure to nearby nature in residential or working environments will require careful research.

At present, public funds are still the main source of direct and indirect payments for healthcare services; without a clear economic rationale for these nature-based, health-promoting activities and ecosystem services, it will be difficult to effectively promote them in policy and planning settings. Widespread adoption hinges on three professional groups: public health researchers and clinicians, urban planners, and landscape architects who necessarily unite at the convergence of human health, urban resilience, and ecology. Burgeoning popular interest in personal health and well-being is the fulcrum around which this discussion will continue to revolve; as a result, translation of research and education remain a critical contribution to a new heath-centric form of ecological stewardship.

Workshop Statement

Five Action Areas of the Natural Environments Initiative

1. Empowering a public policy statement that supports the relationship between human health and exposure to natural environments, including the living/non-living components within such environments
2. Integrating access to nature with health care services to support prevention of illness and promotion of health
3. Promoting equitable access to natural environments
4. Developing personal, scientific, and professional appreciation for the strengths and limitations of the connections between nature and health
5. Refining research and design criteria to assist in the planning and evaluation of salutogenic environments.

AIM:

The Basic Strategies for Health Promotion

- **Advocate:**

  Access to nature supports healthy social, physical, and psychological development. Preservation and enhancement of the natural environment should take factors that support human health into consideration.

- **Invest:**

  Equitable access to natural environments helps most individuals—particularly those in socioeconomically disadvantaged communities or regions—reach their highest attainable quality of life.

- **Mediate:**

  Health promotion through access to nature cannot be mediated by the health sector alone; rather, its success will depend on the collaboration and contribution of citizens in a variety of sectors, including but not limited to, government, community groups, corporate and business groups, non-profit organizations, educational institutions, and media outlets.

Photo Credit Eric Chan

References

[1] Steffen W, Crutzen PJ, McNeill JR: **The anthropocene: are humans now overwhelming the great forces of nature?** *Ambio* 2007, **36:614-21.**

[2] Haase D, Kabisch N, Haase A: **Endless urban growth? On the mismatch of population, household and urban land area growth and its effects on the urban debate.** *PLoS One* 2013, **8**:e66531.

[3] Haase D, Frantzeskaki N, Elmqvist T: **Ecosystem services in urban landscapes: practical applications and governance implications.** *Ambio* 2014, **43**:407-12

[4] Seto KC, Güneralp B, Hutyra LR: **Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools.** *ProcNatlAcadSci U S A* 2012, **109**:16083-8.

[5] United Nations: **World Urbanization Prospects:** The 2011 Revision: New York; 2012.

[6] Seitzinger SP, Svedin U, Crumley CL, Steffen W, Abdullah SA, Alfsen C, Broadgate WJ, et al : **Planetary stewardship in an urbanizing world: beyond city limits.** *Ambio* 2012, **41:**787-94

[7] Schewenius M, McPhearson T, Elmqvist T: **Opportunities for Increasing Resilience and Sustainability of Urban Social-Ecological Systems: Insights from the URBES and the Cities and Biodiversity Outlook Projects.** *Ambio* 2014, **43**:434-44;

[8] Kareiva P, Lalasz R, Marvier M: **Conservation in the Anthropocene.** Breakthrough J 2012, 2:26-36.[9] Eckert S Kohler S: **Urbanization and Health in developing countries: a systematic review.** World Health Pop 2014, **15**:7-20.

[10] Penkalla AM Kohler S: **Urbanicity and mental health.** *Eur J Mental Health* 2014, **9**:1-7.

[11] Cyril S, Oldroyd JC, Renzaho A: **Urbanisation, urbanicity, and health: a systematic review of the reliability and validity of urbanicity scales.** *BMC Public Health* 2013, **13**:513.

[12] Galea S, Uddin M, Koenen K: **The urban environment and mental disorders: Epigenetic links.** Epigenetics 2011, **6**:400-4.

[13] Ginter E, Simko V: **Type 2 diabetes mellitus, pandemic in 21st century.** *AdvExp Med Biol* 2012, 77**1**:42-50.

[14] Gong P, Liang S, Carlton EJ, Jiang Q, Wu J, Wang L, Remais JV: **Urbanisation and health in China.** *Lancet* 2012, **379**:843-52.

[15] Danaei G, Singh GM, Paciorek CJ, Lin JK, Cowan MJ, Finucane MM, Farzadfar F, Stevens GA, Riley LM, Lu Y, Rao M, Ezzati M; Global Burden of Metabolic Risk Factors of Chronic Diseases Collaborating Group: **The global cardiovascular risk transition:**

associations of four metabolic risk factors with national income, urbanization, and Western diet in 1980 and 2008. *Circulation* 2013, **127**:1493-502, 1502e1-8.

[16] Adediran OS, Adebayo PB, Akintunde AA: **Anthropometric differences among natives of Abuja living in urban and rural communities: correlations with other cardiovascular risk factors.** BMC Res Notes 2013, **6**:123.

[17] Wagner KH, Brath H: **A global view on the development of non communicable diseases.** *Prev Med* 2012, **54** Suppl:S38-41.

[18] Delisle H, Ntandou-Bouzitou G, Agueh V, Sodjinou R, Fayomi B: **Urbanisation, nutrition transition and cardiometabolic risk: the Benin study.** *Br J Nutr* 2012, **107**:1534-44.

[19] Ng SW, Howard AG, Wang HJ, Su C, Zhang B: **The physical activity transition among adults in China: 1991-2011.** *Obes Rev* 2014, **15** Suppl 1:27-36.

[20] Zhuo X, Boone CG, Shock EL: **Soil lead distribution and environmental justice in the Phoenix metropolitan region**. *Environ Justice* 2012, 5:206-13.

[21] Bryson J: **Brownfields Gentrification: Redevelopment Planning and Environmental Justice in Spokane, Washington**. *Environ Justice* 2012, 5:26-31.

[22] Boehmer TK, Foster SL, Henry JR, Woghiren-Akinnifesi EL, Yip FY: **Residential proximity to major highways - United States, 2010**. *MMWR Surveill*2013, **62** Suppl 3:46-50.

[23] Bentley M: **An ecological public health approach to understanding the relationships between sustainable urban environments, public health and social equity**. *Health Promot Int* 2014, 29:528-37.

[24] Svendsen ES, Baine G, Northridge ME, Campbell LK, Metcalf SS: **Recognizing resilience**. *Am J Public Health* 2014, 104:581-3.

[25] Wu G, Feder A, Cohen H, Kim JJ, Calderon S, Charney DS, Mathé AA: **Understanding resilience**. *Front Behav Neurosci* 2013, **7**:1-15.

[26] Gifford R: **Environmental Psychology Matters**. *Annu Rev Psychol* 2014, 65:541-79.

[27] Völker S, Kistemann T: **"I'm always entirely happy when I'm here!" Urban blue enhancing human health and well-being in Cologne and Düsseldorf, Germany**. *Soc Sci Med* 2013, **78**:113-24.

[28] Logan AC, Selhub EM: **Vis Medicatrix naturae: does nature "minister to the mind"?** *Biopsychosoc Med* 2012, **6**:11.

[29] Rottenberg J, Yaroslavsky I, Carney RM, Freedland KE, George

CJ, Baji I, Dochnal R, Gádoros J, Halas K, Kapornai K, Kiss E, Osváth V, Varga H, Vetró A, Kovacs M: **The association between major depressive disorder in childhood and risk factors for cardiovascular disease in adolescence**. Psychosom Med 2014, **76**:122-7.

[30] Marazziti D, Rutigliano G, Baroni S, Landi P, Dell'Osso L: **Metabolic syndrome and major depression**. *CNS Spectr* 2014, **19**:293-304.

[31] Wu SF, Young LS, Yeh FC, Jian YM, Cheng KC, Lee MC: **Correlations among social support, depression, and anxiety in patients with type-2 diabetes**. *J Nurs Res* 2013, **21**:129-38.

[32] Arigo D, Smyth JM, Haggerty K, Raggio GA: **The social context of the relationship between glycemic control and depressive symptoms in type 2 diabetes**. *Chronic Illn* 2014 In Press.

[33] Riumallo-Herl CJ, Kawachi I, Avendano M: **Social capital, mental health and biomarkers in Chile: Assessing the effects of social capital in a middle-income country**. *Soc Sci Med* 2014, **105**:47-58.

[34] Maas J, Verheij RA, de Vries S, Spreeuwenberg P, Schellevis FG, Groenewegen PP: **Morbidity is related to a green living environment.** *J Epidemiol Community Health* 2009, **63:**967–973.

[35] Gladwell VF, Brown DK, Wood C, Sandercock GR, Barton JL: The great outdoors: how a green exercise environment can benefit all. *Extrem Physiol Med* 2013, **2**:3.

[36] Nieuwenhuijsen MJ, Kruize H, Gidlow C, Andrusaityte S, Antó JM, Basagaña X, et al: **Positive health effects of the natural outdoor environment in typical populations in different regions in Europe (PHENOTYPE): a study programme protocol**. *BMJ Open* 2014, **4**:e004951.

[37] Barton J, Pretty J: **What is the best dose of nature and green exercise for improving mental health? A multi-study analysis**. *Environ Sci Technol* 2010, **44**:3947-55.

[38] Karjalainen E, Sarjala T, Raitio H: **Promoting human health through forests: overview and major challenges**. *Environ Health Prev Med* 2010,**15**:1-8.

[39] Shuval K, Hébert ET, Siddiqi Z, Leonard T, Lee SC, Tiro JA, McCallister K, Skinner CS: **Impediments and facilitators to physical activity and perceptions of sedentary behavior among urban community residents: the Fair Park Study**. *Prev Chronic Dis*. 2013,**10**:E177.

[40] Holtan M, et al: **Social life under cover: tree canopy and social capital in Baltimore, Maryland**. *Environ Behav* 2014, In Press.

[41] Singh GK, Siahpush M: **Widening Rural-Urban Disparities in All-Cause Mortality and Mortality from Major Causes of Death in the USA, 1969-2009**. *J Urban Health* 2013 In Press.

[42] Kite HA, Gollust SE, Callanan RA, Weisman SR, Benning SJ, Nanney MS: **Uses of research evidence in the state legislative process to promote active environments in Minnesota**. *Am J Health Promot* 2014, **28**(3 Suppl):S44-6.

[43] Dallimer M, Tang Z, Bibby PR, Brindley P, Gaston KJ, Davies ZG: **Temporal changes in greenspace in a highly urbanized region**. *Biol Lett* 2011, **7**:763-6.

[44] Vemuri AW, Grove MJ, Wilson MA, Burch WR: **A tale of two scales: evaluating the relationship among life satisfaction, social capital, income, and the natural environment at the individual and neighborhood levels in metropolitan Baltimore.** *Environ Behav* 2011, **43:**3–25.

[45] Sugiyama T, Leslie E, Giles-Corti B, Owen N: **Associations of neighbourhood greenness with physical and mental health: do walking, social coherence and local social interaction explain the relationships?** *J Epidemiol Community Health* 2008, **62**:e9.

[46] Maas J, Verheij RA, GroenewegenPP, de Vries S, Spreeuwenberg P: **Green space, urbanity, and health: how strong is the relation?***J Epidemiol Community Health*2006 Jul;60(7):587-92.

[47] Stigsdotter UK, Ekholm O, Schipperijn J, Toftager M, Kamper-Jørgensen F, Randrup TB: **Health promoting outdoor environments – associations between green space, and health, health-related quality of life and stress based on a Danish national representative survey.***Scand J Pub Health* 2010, **38:**411–417.

[48] Nutsford D, Pearson AL, Kingham S: **An ecological study investigating the association between access to urban green space and mental health**. *Public Health* 2013, **127**:1005-11.

[49] Beyer K, Kaltenbach A, Szabo A, Bogar S, Nieto FJ, Malecki KM: **Exposure to neighborhood green space and mental health**. *Int J Environ Public Health Res* 2014, **11**:3453-72.

[50] Alcock I, White MP, Wheeler BW, Fleming LE, Depledge MH: **Longitudinal effects on mental health of moving to greener and less green urban areas**. *Environ Sci Technol* 2014, **48**: 1247-1255.

[51] Speldewinde PC, Cook A, Davies P, Weinstein P: **A relationship between environmental degradation and mental health in rural Western Australia**. *Health Place* 2009, **15**:865-72.

[52] White MP, Alcock I, Wheeler BW, Depledge MH: **Coastal proximity, health and well-being: results from a longitudinal panel survey**. *Health Place* 2013, **23**:97-103.

[53] Astell-Burt T, Feng X, Kolt GS: **Does access to neighbourhood green space promote a healthy duration of sleep? Novel findings from a cross-sectional study of 259 319 Australians**. *BMJ Open* 2013, **3**:8.

[54] Wong ML, Lau EY, Wan JH, Cheung SF, Hui CH, Mok DS: **The interplay between sleep and mood in predicting academic functioning, physical health and psychological health: a longitudinal study**. *J Psychosom Res* 2013, **74**:271-7.

[55] Ford ES, Li C, Wheaton AG, Chapman DP, Perry GS, Croft JB: **Sleep duration and body mass index and waist circumference among US adults**. Obesity 2014, **22**:598-607.

[56] Bedrosian TA, Nelson RJ: **Influence of the modern light environment on mood**. *Mol Psychiatry* 2013, **18**:751-7.

[57] Thompson CW, Roe J, Aspinall P, Mitchell R, Clow A, Miller D: **More green space is linked to less stress in deprived communities: evidence from salivary cortisol patterns**. *Landscape Urban Plan* 2012, **105**, 221-29.

[58] Roe JJ, Thompson CW, Aspinall PA, Brewer MJ, Duff EI, Miller D, Mitchell R, Clow A: **Green space and stress: evidence from cortisol measures in deprived urban communities**. *Int J Environ Res Public Health* 2013, **10**:4086-103.

[59] Laurent O, Wu J, Li L, Milesi C: **Green spaces and pregnancy outcomes in Southern California**. *Health Place* 2013, **24**:190-5.

[60] Vigod SN, Tarasoff LA, BryjaB, Dennis CL, Yudin MH, Ross LE: **Relation between place of residence and postpartum depression**. *CMAJ* 2013, **185**:1129-35.

[61] Takano T, Nakamura K, Watanabe M: **Urban residential environments and senior citizens' longevity in megacity areas: the importance of walkable green spaces**. *J Epidemiol Community Health* 2002, **56**:913-8.

[62] Li Q, Kobayashi M, Kawada T: **Relationships between percentage of forest coverage and standardized mortality ratios (SMR) of cancers in all Prefectures in Japan.** *Open Pub Health J* 2008, **1**:1–7.

[63] Takano T, Fu J, Nakamura K, Uji K, Fukuda Y, Watanabe M, Nakajima H: **Age-adjusted mortality and its association to variations in urban conditions in Shanghai.** *Health Policy* 2002, **61**:239–253.

[64] Villeneuve PJ, Jerrett M, Su JG, Burnett RT, Chen H, Wheeler AJ, Goldberg MS: **A cohort study relating urban green space with mortality in Ontario, Canada**. *Environ Res* 2012, **115**:51-8.

[65] Hu Z, Liebens J, Rao KR: **Linking stroke mortality with air pollution, income, and greenness in northwest Florida: an**

ecological geographical study. *Int J Health Geogr* 2008, **7:**20.

[66] Wilker EH, Wu CD, McNeely E, Mostofsky E, Spengler J, Wellenius GA, Mittleman MA: Green space and mortality following ischemic stroke. *Environ Res* 2014, **133**:42-8.

[67] Mitchell R, Popham F: **Effect of exposure to natural environment on health inequalities: an observational population study.** *Lancet* 2008, **372:**1655–1660.

[68] Lovasi GS, Schwartz-Soicher O, Quinn JW, Berger DK, Neckerman KM, Jaslow R, Lee KK, Rundle A:**Neighborhood safety and green space as predictors of obesity among preschool children from low-income families in New York City**. *Prev Med* 2013, **57**:189-93.

[69] Troy A, Grove JA, O'Neil-Dunne J:**The relationship between tree canopy and crime rates across an urban–rural gradient in the greater Baltimore region.** *Landscape Urban Plan* 2012, **106**:262-70.

[70] Donovan GH, Prestemon JP: **The effect of trees on crime in Portland, Oregon**. *Environ Behavior*2012, **44**:3-30.

[71] Lachowycz K, Jones AP: **Does walking explain associations between access to greenspace and lower mortality?** Soc Sci Med 2014,**107**:9-17.

[72] Astell-Burt T, Feng X, Kolt GS: **Is neighborhood green space associated with a lower risk of type 2 diabetes? Evidence from 267,072 Australians**. *Diabetes Care* 2014, **37**:197-201.

[73] Mezuk B, Chaikiat Å, Li X, Sundquist J, Kendler KS, Sundquist K: **Depression, neighborhood deprivation and risk of type 2 diabetes**. *Health Place* 2013, **23**:63-9.

[74] Hansen A, Bi L, Saniotis A, Nitschke M: **Vulnerability to extreme heat and climate change: is ethnicity a factor?** *Glob Health Action* 2013, **6**:21364.

[75] Huang G, Zhou W, Cadenasso ML: **Is everyone hot in the city? Spatial pattern of land surface temperatures, land cover and neighborhood socioeconomic characteristics in Baltimore, MD**. *J Environ Manage* 2011, **92**:1753-9.

[76] Allen J, Balfour R, Bell R, Marmot M: **Social determinants of mental health**. *Int Rev Psychiatry* 2014, **26**:392-407.

[77] Marmot M, Allen JJ: **Social determinants of health equity**. *Am J Public Health* 2014, **104** Suppl 4:S517-9.

[78] Annerstedt M, Ostergren PO, Björk J, Grahn P, Skärbäck E, Währborg P: **Green qualities in the neighbourhood and mental health - results from a longitudinal cohort study in Southern Sweden**. *BMC Public Health* 2012, **12**:337.

[79] Richardson EA, Mitchell R, Hartig T, de Vries S, Astell-Burt T, Frumkin H: **Green cities and health: a question of scale?** *J Epidemiol Community Health* 2012, **66**:160-5.

[80] Richardson E, Pearce J, Mitchell R, Day P, Kingham S: **The association between green space and cause-specific mortality in urban New Zealand: an ecological analysis of green space utility**. *BMC Public Health* 2010, **10**:240.

[81] Storgaard RL, Hansen HS, Aadahl M, Glümer C.: **Association between neighborhood green space and sedentary leisure time in a Danish population**. *Scand J Public Health* 2013, 41:846-52.

[82] Tamosiunas A, Grazuleviciene R, Luksiene D, Dedele A, Reklaitiene R, Baceviciene M, Vencloviene J, Bernotiene G, Radisauskas R, Malinauskiene V, Milinaviciene E, Bobak M, Peasey A, Nieuwenhuijsen MJ: **Accessibility and use of urban green spaces, and cardiovascular health: findings from a Kaunas cohort study**. *Environ Health* 2014, 13:20.

[83] Nowak DJ, Hirabayashi S, Bodine A, Hoehn R: **Modeled PM2.5 removal by trees in ten U.S. cities and associated health effects**. *Environ Pollut* 2013, **178**:395-402.

[84] Nowak DJ, Hirabayashi S, Bodine A, Greenfield E: **Tree and forest effects on air quality and human health in the United States.** *Environ Pollut* 2014, **193**:119-29.

[85] Caron J, Liu A: **Factors associated with psychological distress in the Canadian population: a comparison of low-income and non low-income sub-groups**. *Community Ment Health J* 2011, **47**:318-30.

[86] Bocquier A, Cortaredona S, Verdoux H, Sciortino V, Nauleau S, Verger P: **Social inequalities in new antidepressant treatment: a study at the individual and neighborhood levels**. *Ann Epidemiol* 2013, **23**:99-105.

[87] Castetbon K, Méjean C, Deschamps V, Bellin-Lestienne C, Oleko A, Darmon N, Hercberg S: **Dietary behaviour and nutritional status in underprivileged people using food aid (ABENA study, 2004-2005)**. *J Hum Nutr Diet* 2011, **24**:560-71.

[88] Boardman JD, Downey L, Jackson JS, Merrill JB, Saint Onge JM, Williams DR: **Proximate industrial activity and psychological distress**. *Popul Environ* 2008, **30**:3-25.

[89] **Day** PL, **Pearce** J: **Obesity-promoting food environments and the spatial clustering of food outlets around schools**. *Am J Prev Med* 2011, **40**:113-21.

[90] Ross CE, Jang SJ. **Neighborhood disorder, fear, and mistrust: the buffering role of social ties with neighbors**. *Am J Community Psychol* 2000, **28**:401-20.

[91] Marques S, Lima ML: **Living in grey areas: Industrial activity and psychological health.** *J Environ Psychol* 2011, **31**:314-22.

[92] Boehm JK, Williams DR, Rimm EB, Ryff C, KubzanskyLD: **Association between optimism and serum antioxidants in the midlife in the United States study**. *Psychosom Med* 2013, **75**:2-10.

[93] Boehm JK, Williams DR, Rimm EB, Ryff C, Kubzansky LD: **Relation between optimism and lipids in midlife**. *Am J Cardiol* 2013, **111**:1425-31.

[94] Madrigano J, Baccarelli A, Mittleman MA, Sparrow D, Spiro A 3rd, Vokonas PS, Cantone L, Kubzansky L, Schwartz J: **Air pollution and DNA methylation: interaction by psychological factors in the VA Normative Aging Study**. *Am J Epidemiol* 2012, **176**:224-32.

[95] Tsuno YS, Yamazaki Y: **Relationships among sense of coherence, resources, and mental health in urban and rural residents in Japan**. *BMC Public Health* 2012, **12**:1107.

[96] Kakeyama M, Endo T, Zhang Y, Miyazaki W, Tohyama C: **Disruption of paired-associate learning in rat offspring perinatally exposed to dioxins**. *Arch Toxicol* 2013 In Press.

[97] Harley KG, Gunier RB, Kogut K, Johnson C, Bradman A, Calafat AM, Eskenazi B: **Prenatal and early childhood bisphenol A concentrations and behavior in school-aged children**. *Environ Res* 2013, **126**:43-50.

[98] Eum KD, Korrick SA, Weuve J, Okereke O, Kubzansky LD, Hu H, Weisskopf MG: **Relation of cumulative low-level lead exposure to depressive and phobic anxiety symptom scores in middle-age and elderly women**. *Environ Health Perspect* 2012, **120**:817-23.

[99] Bernstein AS: **Biological diversity and public health**. *Annu Rev Public Health* 2014, **35**:153-67.

[100] Donovan GH, Butry DT, Michael YL, Prestemon JP, Liebhold AM, Gatziolis D, Mao MY: **The relationship between trees and human health: evidence from the spread of the emerald ash borer**. *Am J Prev Med* 2013, **44**:139-45.

[101] Speldewinde PC, Cook A, Davies P, Weinstein P: **The hidden health burden of environmental degradation: disease comorbidities and dryland salinity**. *Ecohealth* 2011, **8**:82-92.

[102] Mitchell R: **Is physical activity in natural environments better for mental health than physical activity in other environments?** *SocSci Med* 2013, **91**:130-4.

[103] Astell-Burt T, Mitchell R, Hartig T: **The association between green space and mental health varies across the lifecourse, a longitudinal study**. *J Epidemiol Community Health* 2014, **68**:578-83.

[104] Korpela K: **Developing the environmental self-regulation hypothesis**. Lambert Academic Publishing 2012:1-72.

[105] Myers SS, Patz J: **Emerging threats to human health from global environmental change**. *Ann Rev Environ Resour* 2009, **34**:223-252.

[106] Stenseth NC, Samia NI, Viljugrein H, Kausrud KL, Begon M, Davis S, Leirs H, Dubyanskiy VM, Esper J, Ageyev VS, Klassovskiy NL, Pole SB, Chan KS: **Plague dynamics are driven by climate variation**. *Proc Natl Acad Sci* U S A 2006, **103**:13110-5.

[107] Keesing F, Belden LK, Daszak P, Dobson A, Harvell CD, Holt RD, Hudson P, Jolles A, Jones KE, Mitchell CE, Myers SS, Bogich T, Ostfeld RS: **Impacts of biodiversity on the emergence and transmission of infectious diseases**. *Nature* 2010, **468**:647-52.

[108] Myers SS, Gaffikin L, Golden CD, Ostfeld RS, Redford KH, Ricketts TH, Turner WR, Osofsky SA: **Human health impacts of ecosystem alteration**. *Proc Natl Acad Sci U S A* 2013, **110**:18753-60.

[109] Ostfeld RS: **Biodiversity loss and the rise of zoonotic pathogens**. *Clin Microbiol Infect* 2009, **15** Suppl 1:40-3.

[110] Ostfeld RS, Keesing F: **Effects of host diversity on infectious disease**. *Ann Rev Ecol Evol System* 2012, **43**:157-82.

[111] Cardinale BJ, Duffy JE, Gonzalez A, Hooper DU, Perrings C, Venail P, Narwani A, Mace GM, Tilman D, Wardle DA, Kinzig AP, Daily GC, Loreau M, Grace JB, Larigauderie A, Srivastava DS, Naeem S: **Biodiversity loss and its impact on humanity**. *Nature* 2012, **486**:59-67.

[112] IPCC, 2014: **Summary for policymakers**. In Climate Change 2014: Impacts, adaptation, and vulnerability. Field CB, et al (Eds): Cambridge University Press, Cambridge, United Kingdom and New York, NY. pp 1-32.

[113] Savitz DA, Poole C, Miller WC: **Reassessing the role of epidemiology in public health**. *Am J Public Health* 1999, **89**:1158-61.

[114] Hansen R, Pauleit S: **From multifunctionality to multiple ecosystem services? A conceptual framework for multifunctionality in green infrastructure planning for urban areas**. *Ambio* 2014, **43**:516-29.

[115] Bentley M. **An ecological public health approach to understanding the relationships between sustainable urban environments, public health and social equity**. Health Promot Int 2014, **29**:528-37.

[116] Wilson EO: **Biophilia**. Harvard University Press, 1984.

[117] Orians JH, Heerwagen JH: **Evolved responses to landscapes**.

In Barkow JH, et al. (Eds). The adpated mind: evolutionary psychology and the generation of culture. Oxford University Press, New York, NY. 1992:555-79.

[118] Appleton J: **The experience of landscape**. John Wiley, New York, NY. 1975.

[119] Kaplan R, Kaplan S: **The experience of nature: a psychological perspective**. Cambridge University Press, New York, NY. 1989.

[120] Heerwagen JH: **Investing in people: The social benefits of sustainable design**. Proceedings of Rethinking Sustainable Construction Symposium. Sarasota, FL, Sept 19-22, 2006.

[121] Ryan, CO, Browning WD, Clancy JO, Andrews SL, Kallianpurkar NB: **Biophilic Design Patterns: Emerging Nature-Based Parameters for Health and Well-Being in the Built Environment**. *Int J Architect Res* 2014, **8**: 62-76.

[122] Huang J, Cedeno-Laurent J, Spengler J: **CityComfort+: A simulation-based method for predicting mean radiant temperature in dense urban areas**. *Build Environ* 2014, **80**:84-95.

[123] Ulrich RS, Simons RF, Losito BD, Fiorito E, Miles MA, Zelson M: **Stress recovery during exposure to natural and urban environments.** *J Environ Psychol* 1991, **11:**201–230.

[124] Li Q, Kawada T: **Effect of forest environments on human natural killer (NK) activity**. *Int J Immunopathol Pharmacol* 2011, **24**(1 Suppl):39S-44S.

[125] Zhang JW, Piffa PK, Iyerb R, Spassena K, Keltner D: **An occasion for unselfing: Beautiful nature leads to prosociality**. *J Environ Psychol* 2014, **37**:61-72.

[126] Faber Taylor A., Kuo FE, Sullivan WC: **Views of nature and self-discipline: Evidence from inner-city children**. *J Environ Psychol* 2002, **22**: 49-63.

[127] Berman MG, Kross E, Krpan KM, Askren MK, Burson A, Deldin PJ, Kaplan S, Sherdell L, Gotlib IH, Jonides J: **Interacting with nature improves cognition and affect for individuals with depression**. *J Affect Disord* 2012, **140**:300-5.

[128] Hartig T, Evan GW, Jamner LD, Davis DS, Garling T: Tracking **restoration in natural and urban field settings**. *J Environ Psychol* 2003, **23**:109-23.

[129] Berto R: **Exposure to restorative environments helps restore attentional capacity.** *J Environ Psychol* 2005, **25:**249–259.

[130] Jahncke H, Hygge S, Halin N, Green AM, Dimberg K: **Open-plan office noise: Cognitive performance and restoration.** *Journal of Environmental Psychology* 2011, **31**:373-382.

[131] Atchley RA, Strayer DL, Atchley P: **Creativity in the wild: improving creative reasoning through immersion in natural settings**. *PLoS One* 2012, **7**:e51474.

[132] Berman MG, Jonides J, Kaplan S: **The cognitive benefits of interacting with nature.** *Psychol Sci* 2008, **19:**1207–1212.

[133] Shin WS, Shin CS, Yeoun PS, Kim JJ: **The influence of interaction with forest on cognitive function.** *Scand J Forest Res* 2011, **26:**595–598.

[134] Faber-Taylor A, Kuo FE: **Children with attention deficits concentrate better after walk in the park.** *J Atten Disord* 2009, **12:**402–409.

[135] Ryan R, Weinstein N, Bernstein J, Brown KW, Mistretta L, Gagne M: **Vitalizing effects of being outdoors and in nature.** *J Environ Psychol* 2010, **30:**159–168.

[136] Tyrväinen L, Ojala A, Korpela K, Lanki T, Tsunetsugu Y, Kagawa T: **The influence of urban green environments on stress relief measures: a field experiment**. *J Environ Psychol* 2014, **38**:1-9.

[137] Park BJ, Tsunetsugu Y, Kasetani T, Kagawa T, Miyazaki Y: **The physiological effects of shinrin-yoku (taking in the forest atmosphere or forest bathing): evidence from field experiments in 24 forests across Japan.** *Environ Health Prev Med* 2010, **15:**18–26.

[138] Tsunetsugu Y, Park BJ, Miyazaki Y: **Trends in research related to "Shinrin-yoku" (taking in the forest atmosphere or forest bathing) in Japan.** *Environ Health Prev Med* 2010, **15:**27–37.

[139] Toda M, Den R, Hasegawa-Ohira M, Morimoto K: **Effects of woodland walking on salivary stress markers cortisol and chromogranin A**. *Complement Ther Med* 2013, **21**:29-34.

[140] Mao GX, Cao YB, Lan XG, He ZH, Chen ZM, Wang YZ, Hu XL, Lv YD, Wang GF, Yan J: **Therapeutic effect of forest bathing on human hypertension in the elderly**. *J Cardiol* 2012, **60**:495-502.

[141] Mao GX, Lan XG, Cao YB, Chen ZM, He ZH, Lv YD, Wang YZ, Hu XL, Wang GF, Yan J: **Effects of short-term forest bathing on human health in a broad-leaved evergreen forest in Zhejiang Province, China**. *Biomed Environ Sci* 2012, **25**:317-24.

[142] Horiuchi M, Endo J, Akatsuka S, Uno T, Hasegawa T, Seko Y: **Influence of forest walking on blood pressure, Profile of Mood States, and stress markers from the viewpoint of aging**. *J Aging Gerontol* 2013, **1**:9-17.

[143] Sung J, Woo JM, Kim W, Lim SK, Chung EJ: **The effect of cognitive behavior therapy-based "forest therapy" program on blood pressure, salivary cortisol level, and quality of life in**

elderly hypertensive patients. *Clin Exp Hypertens* 2012, **34**:1-7.

[144] Song C, Joung D, Ikei H, Igarashi M, Aga M, Park BJ, Miwa M, Takagaki M, Miyazaki Y: **Physiological and psychological effects of walking on young males in urban parks in winter**. *J Physiol Anthropol* 2013, **32**:18.

[145] Li Q, Morimoto K, Kobayashi M, Inagaki H, Katsumata M, Hirata Y, Hirata K, Suzuki H, **Li** YJ, Wakayama Y, Kawada T, Park BJ, Ohira T, Matsui N, Kagawa T, Miyazaki Y, Krensky AM: **Visiting a forest, but not a city, increases human natural killer activity and expression of anti-cancer proteins**. *Int J Immunopathol Pharmacol* 2008, **21**:117-27.

[146] Ziska LH, Bunce JA, Shimono H, Gealy DR, Baker JT, Newton PC, Reynolds MP, Jagadish KS, Zhu C, Howden M, Wilson LT: **Food security and climate change: on the potential to adapt global crop production by active selection to rising atmospheric carbon dioxide**. *Proc Biol Sci* 2012, **279**:4097-105.

[147] Ziska LH: **Increasing minimum daily temperatures are associated with enhanced pesticide use in cultivated soybean along a latitudinal gradient in the mid-western United States**. *PLoS One* 2014, **9**:e98516.

[148] Ogden NH, Radojevic M, Wu X, Duvvuri VR, Leighton PA, Wu J: **Estimated effects of projected climate change on the basic reproductive number of the Lyme disease vector Ixodes scapularis**. *Environ Health Perspect* 2014, **122**:631-8.

[149] Albrecht G, Sartore GM, Connor L, Higginbotham N, Freeman S, Kelly B, Stain H, Tonna A, Pollard G: **Solastalgia: the distress caused by environmental change**. *Australas Psychiatry* 2007, **15** Suppl 1:S95-8.

[150] Ribeiro AI, Mitchell R, Carvalho MS, de Pina Mde F: **Physical activity-friendly neighbourhood among older adults from a medium size urban setting in Southern Europe**. *Prev Med* 2013, **57**:664-70.

[151] Carek PJ, Laibstain SE, Carek SM: **Exercise for the treatment of depression and anxiety**. *Int J Psychiatry Med* 2011, **41**:15-28.

[152] Ord K, Mitchell R, Pearce J: I**s level of neighbourhood green space associated with physical activity in green space?** *Int J Behav Nutr Phys Act* 2013, **10**:127.

[153] Tseng M, Thornton LE, Lamb KE, Ball K, Crawford D: **Is neighbourhood obesogenicity associated with body mass index in women? Application of an obesogenicity index in socioeconomically disadvantaged neighbourhoods**. *Health Place* 2014, **30**C:20-27.

[154] Lachowycz K, Jones AP: **Greenspace and obesity: a systematic review of the evidence**. *Obes Rev* 2011, **12**:e183-9.

[155] Leslie E, Cerin E, Kremer P: **Perceived neighborhood environment and park use as mediators of the effect of area socio-economic status on walking behaviors**. *J Phys Act Health* 2010, **7**:802-10.

[156] Focht B: **Brief walks in outdoor and laboratory environments: effects on affective responses, enjoyment, and intentions to walk for exercise.** *Res Q Exerc Sport* 2009, **80:**611–620.

[157] Neuvonen M., Sievänen T, Tönnes S, Koskela T: **Access to green areas and the frequency of visits - A case study in Helsinki**. *Urban Forest Urban Green* 2007, **6**: 235-247.

[158] Groenewegen P, van den Berg AE, Maas J, Verheij RA, de Vries S: **Is a Green Residential Environment Better for Health? If So, Why?** *Ann Assoc Am Geogr* 2012, **102**:996-1003.

[159] Marselle MR, Irvine KN, Warber SL: **Walking for well-being: are group walks in certain types of natural environments better for well-being than group walks in urban environments?** *Int J Environ Res Public Health* 2013, **10**:5603-28.

[160] Hug SM, Hartig T, Hansmann R, Seeland K, Hornung R: **Restorative qualities of indoor and outdoor exercise settings as predictors of exercise frequency.** *Health Place* 2009, **15:**971–980.

[161] Gathright J, Yamada Y, Morita M: **Comparison of the physiological and psychological benefits of tree and tower climbing.** *Urban Forest Urban Green* 2006, **5:**141–149.

[162] Hawkins JA, Thirlaway KJ, Backx K, Clayton DA: **Allotment gardening and other leisure activities for stress reduction and healthy aging.** *HortTechnol* 2011, **21:**577–585.

[163] Duvall J, De Young R: **Some strategies for sustaining a walking routine: insights from experienced walkers**. *J Phys Act Health* 2013, **10**:10-8.

[164] DeWolfe J, Waliczek TM, Zajicek JM: **The relationship between levels of greenery and landscaping at track and field sites, anxiety, and sports performance of collegiate and field athletes.** *HortTechnol* 2011, **21:**329–335.

[165] Chang CY, Lin YH, Chou MT: **Experiences and stress reduction of viewing natural environmental settings.** *ActaHortic* 2008, **775:**139–146.

[166] Chang CY, Hammitt WE, Chen PK, Machnik L, Su WC: **Psychophysiological responses and restorative values of natural environments in Taiwan.** *Landscape Urban Plan* 2008, **85:**79–84.

[167] Ulrich RS: **Natural versus urban scenes: some psychophysiological effects.** *Envriron Behav* 1981, **13:**523–556.

[168] Aspinall P, Mavros P, Coyne R, Roe J: **The urban brain: analysing outdoor physical activity with mobile EEG**. *Br J Sports Med* 2013 In Press.

[169] Tsunetsugu Y, Miyazaki Y: **Measurement of absolute hemoglobin concentrations of prefrontal region by near-infrared time-resolved spectroscopy: examples of experiments and prospects.** *J Physiol Anthropol Appl Human Sci* 2005, **24:**469–472.

[170] Tinio P, Leder H: **Natural scenes are indeed preferred, but image quality might have the last word.** *Psychol Aesthet Creat Arts* 2009, **3:**52–56.

[171] Korpela K, Klemettila T, Hietanen JK: **Evidence for rapid affective evaluation of environmental scenes**. *Environ Behav* 2002, **34**:634-50.

[172] Hietanen JK, Klemettilä T Kettunen JE, Korpela KM: **What is a nice smile like that doing in a place like this? Automatic affective responses to environments influence the recognition of facial expressions.** *Psychological Research* 2007, **71**:539-552.

[173] Kim TH, Jeong GW, Baek HS, Kim GW, Sundaram T, Kang HK, Lee SW, Kim HJ, Song JK: **Human brain activation in response to visual stimulation and rural urban scenery pictures: a functional magnetic resonance imaging study.** *Sci Total Environ* 2010, **408:**2600–2607.

[174] Kim GW, Song JK, Jeong GW: **Neuro-anatomical evaluation of human suitability for rural and urban environment by using fMRI.** *Korean J Med Phys* 2011, **22:**18–27.

[175] Kim GW, Jeong GW, Kim TH, Baek HS, Oh SK, Kang HK, Lee SG, Kim YS, Song JK: **Functional neuroanatomy associated with natural and urban scenic views in the human brain: 3.0 T functional MR imaging.** *Korean J Radiol* 2010, **11:**507–513.

[176] Lederbogen F, Kirsch P, Haddad L, Streit F, Tost H, Schuch P, Wüst S, Pruessner JC, Rietschel M, Deuschle M, Meyer-Lindenberg A: **City living and urban upbringing affect neural social stress processing in humans.** *Nature* 2011, **474:**498–501.

[177] Kim TH, Song JK, Jeong GW: **Neural responses to the human color preference for assessment of eco-friendliness: a functional magnetic resonance imaging study**. *Int J Environ Res* 2012, **6**:953-60.

[178] deFockert JW, Caparos S, Linnell KJ, Davidoff J: **Reduced distractibility in a remote culture**. *PLoS One*2011, **6**:e26337.

[179] Linnell KJ, Caparos S, de Fockert JW, Davidoff J: **Urbanization decreases attentional engagement**. *J Exp Psychol Hum Percept Perform* 2013, **39**:1232-47.

[180] Brown DK, Barton JL, Gladwell VF: **Viewing nature scenes positively affects recovery of autonomic function following acute-mental stress**. *Environ Sci Technol* 2013, **47**:5562-9.

[181] Berto R, Baroni MR, Zainaghi A, Bettella S: **An exploratory study of the effect of high and low fascination environments on attention fatigue.** *J Environ Psychol* 2010, **30:**494–500.

[182] Joye Y, Pals R, Steg L, Evans BL: **New methods for assessing the fascinating nature of nature experiences**. *PLoS One* 2013, **8**:e65332.

[183] Ulrich RS: **View through a window may influence recovery from surgery**. *Science* 1984, **224**:420-1.

[184] Matsuoka R: **Student performance and high school landscapes: examining the links.** *Landscape Urban Plan* 2010, **97:**273–282.

[185] Wu CD, McNeely E, Cedeño-Laurent JG, Pan WC, Adamkiewicz G, Dominici F, Lung SC, Su HJ, Spengler JD: **Linking student performance in massachusetts elementary schools with the "greenness" of school surroundings using remote sensing**. *PLoS One* 2014, **9**:e108548.

[186] Li Q, Kobayashi M, Inagaki H, Hirata Y, **Li** YJ, Hirata K, Shimizu T, Suzuki H, Katsumata M, Wakayama Y, Kawada T, Ohira T, Matsui N, Kagawa T: **A day trip to a forest park increases human natural killer activity and the expression of anti-cancer proteins in male subjects**. *J Biol Regul Homeost Agents* 2010, **24**:157-65.

[187] Li Q, Morimoto K, Kobayashi M, Inagaki H, Katsumata M, Hirata Y, Hirata K, Suzuki H, Li YJ, Wakayama Y, Kawada T, Park BJ, Ohira T, Matsui N, Kagawa T, Miyazaki Y, Krensky AM: **Visiting a forest, but not a city, increases human natural killer activity and expression of anti-cancer proteins**. *Int J Immunopathol Pharmacol* 2008, **21**:117-27.

[188] Lv XN, Liu ZJ, Zhang HJ, Tzeng CM: **Aromatherapy and the central nerve system (CNS): therapeutic mechanism and its associated genes**. *Curr Drug Targets* 2013, **14**:872-9.

[189] Wang XL, Li CR, Xu JW, Hu DM, Zhao ZL, Zhang LD: **Air negative ion concentration in different modes of courtyard forests in southern mountainous areas of Jinan, Shandong Province of East China**. *Ying Yong Sheng Tai XueBao* 2013, **24**:373-8.

[190] Wu CF, Lai CH, Chu HJ, Lin WH:**Evaluating and mapping of spatial air ion quality patterns in a residential garden using a geostatistic method**. *Int J Environ Res Public Health* 2011, **8**:2304-19.

[191] Blackhall K, Appleton S, Cates CJ: **Ionisers for chronic asthma**. *Cochrane Database Syst Rev* 2012,**12**;9.

[192] Perez V, Alexander DD, Bailey WH: **Air ions and mood outcomes: a review and meta-analysis**. *BMC Psychiatry* 2013, **13**:29.

[193] Harmer CJ, Charles M, McTavish S, Favaron E, Cowen PJ: **Negative ion treatment increases positive emotional processing in seasonal affective disorder**. *Psychol Med* 2012, **42**:1605-12.

[194] Annerstedt M, Jönsson P, Wallergård M, Johansson G, Karlson B, Grahn P, Hansen AM, Währborg P: **Inducing physiological stress recovery with sounds of nature in a virtual reality forest--results from a pilot study**. *Physiol Behav* 2013, **118**:240-50.

[195] Saadatmand V, Rejeh N, Heravi-Karimooi M, Tadrisi SD, Zayeri F, Vaismoradi M, Jasper M: **Effect of nature-based sounds' intervention on agitation, anxiety, and stress in patients under mechanical ventilator support: a randomised controlled trial**. *Int J Nurs Stud* 2013, **50**:895-904.

[196] Depledge MH, Stone RJ, Bird WJ: **Can natural and virtual environments be used to promote improved human health and wellbeing?** *Environ Sci Technol* 2011, **45**:4660-5.

[197] Koga K, Iwasaki Y: **Psychological and physiological effect in humans of touching plant foliage - using the semantic differential method and cerebral activity as indicators**. *J Physiol Anthropol* 2013, **32**:7.

[198] Yamane K, Kawashima M, Fujishige N, Yoshida M: **Effects of interior horticultural activities with potted plants on human physiological and emotional status.** *Acta Hortic* 2004, **639:**37–43.

[199] Yanagida F, Srionnual S, Chen YS: **Isolation and characteristics of lactic acid bacteria from koshu vineyards in Japan**. *Lett Appl Microbiol* 2008, **47**:134-9.

[200]Vitali B, Minervini G, Rizzello CG, Spisni E, Maccaferri S, Brigidi P, Gobbetti M, Di Cagno R: **Novel probiotic candidates for humans isolated from raw fruits and vegetables**. *Food Microbiol* 2012, **31**:116-25.

[201] Vokou D, Vareli K, Zarali E, Karamanoli K, Constantinidou HI, Monokrousos N, Halley JM, Sainis I: **Exploring biodiversity in the bacterial community of the Mediterranean phyllosphere and its relationship with airborne bacteria**. *MicrobEcol* 2012, **64**:714-24.

[202] Logan AC, VenketRao A, Irani D: **Chronic fatigue syndrome: lactic acid bacteria may be of therapeutic value**. *Med Hypotheses* 2003, **60**:915-23.

[203] Bested AC, Logan AC, Selhub EM: **Intestinal microbiota, probiotics and mental health: from Metchnikoff to modern advances: Part II - contemporary contextual research**. *Gut Pathog* 2013, **5**:3.

[204] Selhub E, Logan AC: **Your Brain on Nature**. Toronto: John Wiley and Sons; 2012.

[205] Matthews DM, Jenks SM: **Ingestion of Mycobacterium vaccae decreases anxiety-related behavior and improves learning in mice**. *Behav Processes* 2013, **96**:27-35.

[206] Hanski I, von Hertzen L, Fyhrquist N, Koskinen K, Torppa K, Laatikainen T, Karisola P, Auvinen P, Paulin L, Mäkelä MJ, Vartiainen E, Kosunen TU, Alenius H, Haahtela T: **Environmental biodiversity, human microbiota, and allergy are interrelated**. *Proc Natl Acad Sci U S A* 2012, **109**:8334-9.

[207] Kondrashova A, Seiskari T, Ilonen J, Knip M, Hyöty H: **The 'Hygiene hypothesis' and the sharp gradient in the incidence of autoimmune and allergic diseases between Russian Karelia and Finland**. *APMIS* 2013, **121**:478-93.

[208] Bendiks M, Kopp MV: **The relationship between advances in understanding the microbiome and the maturing hygiene hypothesis**. *Curr Allergy Asthma Rep* 2013, **13**:487-94.

[209] George DR: **Harvesting the biopsychosocial benefits of community gardens**. *Am J Public Health* 2013, **103**:e6.

[210] Castro DC, Samuels M, Harman AE: **Growing healthy kids: a community garden-based obesity prevention program**. *Am J Prev Med* 2013, **44**(3 Suppl 3):S193-9.

[211] Litt JS, Soobader MJ, Turbin MS, Hale JW, Buchenau M, Marshall JA: **The influence of social involvement, neighborhood aesthetics, and community garden participation on fruit and vegetable consumption**. *Am J Public Health* 2011, **101**:1466-73.

[212] Zick CD, Smith KR, Kowaleski-Jones L, Uno C, Merrill BJ: **Harvesting more than vegetables: the potential weight control benefits of community gardening**. *Am J Public Health* 2013, **103**:1110-5.

[213] Park, SA, Shoemaker C, Haub M:.**Can older gardeners meet the physical activity recommendationthrough gardening?** *HortTechnology* 2008, **18**:639–43.

[214] Park, SA, Shoemaker C, Haub M:**How to measure exercise intensity of gardening tasks as a physical activity for older adults using metabolic equivalents**. *ActaHortic* 2008, **775**:37–40.

[215] Lee MS, Park BJ, Lee J, Park KT, Ku JH, Lee JW, Oh KO, Miyazaki Y: **Physiological relaxation induced by horticultural activity: transplanting work using flowering plants**.*J PhysiolAnthropol* 2013, **32**:15.

[216] Hayashi N, Wada T, Hirai H, Miyake T, Matsura Y, Shimizu N, Kurooka H, Horiuchi S: **The effects of horticultural activity in a community garden on mood changes**. *Environ Control Biol* 2008,

46:233-40.

[217] Waliczek TM, Zajicek JM, Lineberger RD: **The influence of gardening activities on perceptions of life satisfaction**. Horticult Sci 2005, **40**:1360-1365.

[218] Cammack C, Waliczek TM, Zajicek JM: **The green brigade: The psychological effects of a community-based horticultural program on the self-development characteristics of juvenile offenders**. *Hort Technol* 2002, **12**:82-86.

[219] Gonzalez MT, Hartig T, Patil GG, Martinsen EW, Kirkevold M: **A prospective study of group cohesiveness in therapeutic horticulture for clinical depression**. *Int J Ment Health Nurs* 2011, **20**:119-29.

[220] Gonzalez MT, Hartig T, Patil GG, Martinsen EW, Kirkevold M: **Therapeutic horticulture in clinical depression: a prospective study of active components**. *J Adv Nurs* 2010, **66**:2002-13.

[221] Kotozaki Y: **The psychological effect of horticultural therapy intervention on earthquake-related stress of women in earthquake-related areas**. *J Transl Med Epidemiol* 2014, **2**:1008.

[222] Garvin EC, Cannuscio CC, Branas CC: **Greening vacant lots to reduce violent crime: a randomised controlled trial**. *Inj Prev* 2013, **19**:198-203.

[223] Garvin E, Branas C, Keddem S, Sellman J, Cannuscio C: **More than just an eyesore: local insights and solutions on vacant land and urban health**. *J Urban Health* 2013, **90**:412-26.

[224] Lohr V, Pearson-Mims C:**Children's active and passive interactions with plants influence their attitudes and actions toward trees and gardening as adults**. *Hort-Technology* 2005; **15**:472 76.

[225] Skelly S, Zajicek J:.**The effect of an interdisciplinary garden program on the environmental attitudes of elementary school students**. *HortTechnology* 1998;**8**:579–83.

[226] Taniguchi, T, and R Akamatsu. **The relationship between farming experiences and attitudes toward locally grown foods among Japanese children**. *HortTechnology* 2011; **21**:355–58.

[227] Asah ST, Bengston DN, Westphal LM: **The influence of childhood: operational pathways to adulthood participation in nature-based activities.** *Environ Behav* 2012, 44:545-69.

[228] Thompson C, Aspinall P, Bell S, Findlay C: **It gets you away from everyday life: local woodlands and community use – what makes a difference?** *Landscape Res* 2005, **30:**109–146.

[229] Frantz CM, Mayer FS, Norton C, Rock M: **There is no "I" in nature: the influence of self-awareness on connectedness to**

nature. *J Environ Psychol* 2005, **25:**427–436.

[230] Cheng J, Monroe M: **Connection to nature: children's affective attitude toward nature.** *Environ Behav* 2012, 44:31-49.

[231] Lukin K: **Exciting middle and high school students about immunology: an easy, inquiry-based lesson**. *Immunol Res* 2013, **55**:201-9.

[232] Klemmer C, Waliczek TM, Zajicek J: **Growing minds: The effects of a school gardening program on the science achievement of elementary students**. *HortTechnology* 2005; **15**:448–52.

[233] Smith L, Motsenbocker C:.**Impact of hands-on science through school gardening in Louisiana public elementary schools**. *HortTechnology* 2005; **15**:439–43.

[234] Robinson C, Zajicek J: **Growing minds: The effects of a one-year school garden program on six constructs of life skills of elementary school children**. *HortTechnology* 2005; **15**:453–57.

[235] Kessler R: **Urban gardening: managing the risks of contaminated soil**. *Environ Health Perspect* 2013, **121**:A326-33.

[236] Säumel I, Kotsyuk I, Hölscher M, Lenkereit C, Weber F, Kowarik I**: How healthy is urban horticulture in high traffic areas? Trace metal concentrations in vegetable crops from plantings within inner city neighbourhoods in Berlin, Germany**. *Environ Pollut* 2012, **165**:124-32.

[237] Hardisty DJ, Weber EU: **Discounting future green: money versus the environment**. *J Exp Psychol Gen* 2009, **138**:329-40.

[238] Vlahov D, Galea S: **Urbanization, urbanicity, and health**. *J Urban Health* 2002, **79**(4 Suppl 1):S1-S12.

[239] van der Wal AJ, Schade HM, Krabbendam L, van Vugt M: **Do natural landscapes reduce future discounting in humans?** *Proc Biol Sci* 2013, **280**:20132295.

[240] Nisbet EK, Zelenski JM: **Underestimating nearby nature: affective forecasting errors obscure the happy path to sustainability.***Psychol Sci* 2011, **22:**1101–1106.

[241] Cervinka R, Roderer K, Hefler E: **Are nature lovers happy? On various indicators of well-being and connectedness to nature.** *J Health Psychol* 2012, **17**:379-88.

[242] Nisbet EK, Zelenski JM, Murphy SA: **Happiness is in our nature: exploring nature relatedness as a contributor to subjective well-being.** *J Happiness Stud* 2011, **12:**303–322.

[243] Howell AJ, Dopko RL, Passmore HA, Buro K: **Nature connectedness: associations with well-being and mindfulness.**

Personality Indiv Diff 2011, **51:**166–171.

[244] Shwartz A, Cosquer A, Jaillon A, Piron A, Julliard R, Raymond R, Simon L, Prévot-Julliard AC: **Urban biodiversity, city-dwellers and conservation: how does an outdoor activity day affect the human-nature relationship?** *PLoS One* 2012, **7**:e38642.

[245] Willis KG, Crabtree B: **Measuring Health Benefits of Green Space in Economic Terms**. *In:* Nilsson K, et al (Eds). *Forests, Trees and Human Health*. New York: Springer, 2010, pp.375-402.

[246] Sushinsky JR, Rhodes JR, Possingham HP, Gill TK, Fuller RA: **How should we grow cities to minimize their biodiversity impacts?** *Glob Chang Biol* 2013, **19**:401-10.

[247] Beatley T: Biophilic Cities. Island Press, Washington DC. 2011.

[248] Fuller RA, Irvine KN, Devine-Wright P, Warren PH, Gaston KJ: **Psychological benefits of greenspace increase with biodiversity.** *BiolLett* 2007, **3:**390–394.

[249] Luck GW, Davidson P, Boxall D, Smallbone L: **Relations between urban bird and plant communities and human well-being and connection to nature.** *Conservation Biol* 2011, **25:**816–826.

[250] McLennan JF, Brukman E: **Living Building Challenge 2.0**. International Living Building Initiative April 2010:1-43.

[251] Larco N: **A note from the co-Director**. *The Hub Q News SCI* 2010, **1**:8.

[252] Gómez A, Balsari S, Nusbaum J, Heerboth A, Lemery J: **Perspective: Environment, biodiversity, and the education of the physician of the future**. *Acad Med* 2013, **88:**168-72.

[253] Redshaw CH, Stahl-Timmins WM, Fleming LE, Davidson I, Depledge MH: **Potential changes in disease patterns and pharmaceutical use in response to climate change**. *J Toxicol Environ Health B Crit Rev* 2013, **16**:285-320.

[254] Prince M, Patel V, Saxena S, Maj M, Maselko J, Phillips MR, Rahman A: **No health without mental health.** *Lancet* 2007, **370**:859-77.

[255] Husarewycz MN, El-Gabalawy R, Logsetty S, Sareen J: **The association between number and type of traumatic life experiences and physical conditions in a nationally representative sample**. *Gen Hosp Psychiatry* 2014, **36**:26-32.

[256] Sullivan MD, Katon WJ, Lovato LC, Miller ME, Murray AM, Horowitz KR, Bryan RN, Gerstein HC, Marcovina S, Akpunonu BE, Johnson J, Yale JF, Williamson J, Launer LJ: **Association of depression with accelerated cognitive decline among patients with type 2 diabetes in the ACCORD-MIND trial**. *JAMA Psychiatry*

2013, **70**:1041-7.

[257] Ma Y, Balasubramanian R, Pagoto SL, Schneider KL, Hébert JR, Phillips LS, Goveas JS, Culver AL, Olendzki BC, Beck J, Smoller JW, Sepavich DM, OckeneJK, Uebelacker L, Zorn M, Liu S: **Relations of depressive symptoms and antidepressant use to body mass index and selected biomarkers for diabetes and cardiovascular disease**.*Am J Public Health* 2013, **103**:e34-43.

[258] Currier MB, Nemeroff CB: **Depression as a Risk Factor for Cancer: From Pathophysiological Advances to Treatment Implications**. *Annu Rev Med* 2013 In Press.

[259] Nemeroff CB, Goldschmidt-Clermont PJ: **Heartache and heartbreak--the link between depression and cardiovascular disease**. *Nat Rev Cardiol* 2012, **9**:526-39.

[260] Masand PS, Keuthen NJ, Gupta S, Virk S, Yu-Siao B, Kaplan D: **Prevalence of irritable bowel syndrome in obsessive-compulsive disorder**. *CNS Spectr* 2006, **11**:21-5.

[261] Schmitz N, Gariépy G, Smith KJ, Clyde M, Malla A, Boyer R, Strychar I, Lesage A, Wang J: **Recurrent subthreshold depression in type 2 diabetes: an important risk factor for poor health outcomes**. *Diabetes Care* 2014, 37:970-8.

[262] Matz CJ, Stieb DM, Davis K, Egyed M, Rose A, Chou B, Brion O: **Effects of age, season, gender and urban-rural status on time activity**. *Int J Environ Res Public Health* 2014, **11**:2108-24.

[263] Pergams O, Zaradic P: **Evidence for a fundamental and pervasive shift away from nature-based recreation.** *Proc Nat lAcad Sci U S A* 2008, **105:**2295–2300.

[264] Pergams O, Zaradic P: **Is love of nature in the US becoming love of electronic media? 16-year downtrend in national park visits explained by watching movies, playing video games, internet use, and oil prices.** *J Environ Manage* 2006, **80:**387–393.

[265] Siikamaki J: **Contributions of the US state park system to nature recreation.** *Proc Natl Acad Sci U S A* 2011, **108:**14031–14036.

[266] Ding D, Sugiyama T, Winkler E, Cerin E, Wijndaele K, Owen N: **Correlates of change in adults' television viewing time: a four-year follow-up study**. *Med Sci Sports Exerc* 2012, **44**:1287-92.

[267] Sugiyama T, Salmon J, Dunstan DW, Bauman AE, Owen N: **Neighborhood walkability and TV viewing time among Australian adults**. *Am J Prev Med* 2007, **33**:444-9.

[268] Salmon J, Veitch J, Abbott G, ChinAPaw M, Brug JJ, teVelde SJ, Cleland V, Hume C, Crawford D, Ball K: **Are associations between the perceived home and neighbourhood environment and children's physical activity and sedentary behaviour moderated by urban/rural location?** *Health Place* 2013, 24:44-53.

[269] Tandon PS, Zhou C, Sallis JF, Cain KL, Frank LD, Saelens BE: **Home environment relationships with children's physical activity, sedentary time, and screen time by socioeconomic status**. *Int J Behav Nutr Phys Act* 2012, **9**:88.

[270] Chen W, Lee KH: **Sharing, liking, commenting, and distressed? The pathway between Facebook interaction and psychological distress**. *Cyberpsychol Behav Soc Netw* 2013, **16**:728-34.

[271] Kross E, Verduyn P, Demiralp E, Park J, Lee DS, Lin N, Shablack H, Jonides J, Ybarra O: **Facebook use predicts declines in subjective well-being in young adults**. *PLoS One* 2013, **8**:e69841.

[272] Becker MW, Alzahabi R, Hopwood CJ: **Media multitasking is associated with symptoms of depression and social anxiety**. *Cyberpsychol Behav Soc Netw* 2013, **16**:132-5.

[273] Primack B, Swanier B, Georgiopoulos AM, Land SR, Fine MJ: **Association between media use in adolescence and depression in young adulthood.** *Arch Gen Psychiatry* 2009, **66:**181–188.

[274] Van den Eijnden R, Meerkerk GJ, Vermulst AA, Spijkerman R, Engels RC: **Online communication, compulsive internet use, and psychological well-being among adolescents: a longitudinal study.** *DevPsychol* 2008, **44:**655–665.

[275] Salanova M, Llorens S, Cifre E: **The dark side of technologies: technostress among users of information and communication technologies**. *Int J Psychol* 2013, **48**:422-36.

[276] Lucas M, Mekary R, Pan A, Mirzaei F, O'Reilly EJ, Willett WC, Koenen K, Okereke OI, Ascherio A: **Relation between clinical depression risk and physical activity and time spent watching television in older women: a 10-year prospective follow-up study.** *Am J Epidemiol* 2011, **174:**1017–1027.

[277] Misra S, Stokols D: **Psychological and health outcomes of perceived information overload.** *Environ Behav* 2012, **44**:737-59.

[278] Twenge JM: **Overwhelming evidence for generation Me**. *Emerg Adulthood* 2013, **1**:21-26.

[279] Twenge JM, Kasser T: **Generational changes in materialism and work centrality, 1976-2007: associations with temporal changes in societal insecurity and materialistic role modeling**. *Pers Soc Psychol Bull* 2013, **39**:883-97.

[280] Twenge JM, Campbell WK, Freeman EC: **Generational differences in young adults' life goals, concern for others, and civic orientation, 1966-2009**.*Pers Soc Psychol* 2012, **102**:1045-62.

[281] Kabisch N, Qureshi S, Haase D: **Human-environment interactions in urban green spaces - a systematic review of contemporary issues and prospects for future research**. *Environ*

Impact Assess Rev 2015, 50:25-34.

[282] Gatersleben B, Andrews M: **When walking in nature is not restorative-the role of prospect and refuge**. *Health Place* 2013, **20**:91-101.

[283] Francis J, Wood LJ, Knuiman M, Giles-Corti B: Quality or quantity? **Exploring the relationship between Public Open Space attributes and mental health in Perth, Western Australia**. *Soc Sci Med* 2012, **74**:1570-7.

[284] vanDillen SM, de Vries S, Groenewegen PP, Spreeuwenberg P: **Greenspace in urban neighbourhoods and residents' health: adding quality to quantity**. *J Epidemiol Community Health* 2012, **66**:e8.

[285] Worobey J, Fonseca DM, Espinosa C, Healy S, Gaugler R: **Child outdoor physical activity is reduced by prevalence of the Asian tiger mosquito, Aedesalbopictus**.*J Am Mosq Control Assoc* 2013, **29**:78-80.

[286] Ikegami M, Yoneda M, Tsuji T, Bannai O, Morisawa S: **Effect of Particle Size on Risk Assessment of Direct Soil Ingestion and Metals Adhered to Children's Hands at Playgrounds**. *Risk Anal* 2014, **34**:1677-87.

[287] Astell-Burt T, Feng X, Kolt GS: **Neighbourhood green space and the odds of having skin cancer: multilevel evidence of survey data from 267072 Australians**. *J Epidemiol Community Health* 2014,**68**:370-4.

[288] Astell-Burt T, Feng X, Mavoa S, Badland HM, Giles-Corti B: **Do low-income neighbourhoods have the least green space?** *BMC Public Health* 2014, **14**:292.

[289] Kabisch N, Haase Dl: **Green justice or just green? Provision of urban green spaces in Berlin, Germany**. *Landscape Urban Plann* 2014, **122**:129-39.

[290] Kinzig AP, Warren P, Martin C, Hope D, Katti M: **The effects of human socioeconomic status and cultural characteristics on urban patters of biodiversity**. *Ecology Soc* 2005, **10**:23.

[291] Milner-Gulland EJ, McGregor JA, Agarwala M, Atkinson G, Bevan P, Clements T, Daw T, et al: **Accounting for the impact of conservation on human well-being**. *Conserv Biol* 2014, **28**:1160-6.

[292] Jennings V, Gaither CJ, Gragg RS: **Promoting environmental justice through urban green space access**. *Environ Justice* 2012, **5**:1-7.

[293] http://www.iufro.org/science/task-forces/forests-trees-humans/activities/

[294] http://www.cohabnet.org/

[295]http://www.iucn.org/about/work/programmes/gpap_home/gpap_people/gpap_tilcepa/gpap_healthy/

[296] http://www.nps.gov/public_health/hp/hphp.htm

[297] http://www.cost.eu/domains_actions/fps/Actions/E39