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URBAN NATURE FOR HUMAN HEALTH AND WELL-BEING

A research summary for communicating the health benefits of urban trees and green space

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Introduction

Writers, philosophers, and naturalists have praised the benefits of nature for human health, happiness, and well-being for centuries, but only relatively recently have researchers begun studying and quantifying the complex relationship between human health and nature.

In 1984, Roger Ulrich, professor and director of the Center for Health Systems and Design at Texas A&M University, published the results of a pioneering study that looked at the recovery rates of gall bladder surgery patients in relation to the views from their rooms in a Texas hospital. Some of the patients looked out over a garden and grove of trees, while others had a view of a brick wall. Ulrich found that patients with a natural view spent fewer days in the hospital and used fewer pain medications (Ulrich 1984).

Ulrich's study helped open the door to a new field of inquiry focused on illuminating the ways that nature influences our physical, mental, and social lives. More than three decades later, a broad and diverse body of scientific literature describes the human health value of nature, confirming that trees, parks, gardens, and other natural settings are as essential to livable and sustainable cities as the other critical systems that keep their residents moving and working.

Findings from the current literature indicate the wide range of effects.

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For instance, studies show that–

- People living near parks and green space have less mental distress, are more physically active, and have extended life spans.
- Exposure to nature may impact human mortality from chronic disease.
- When people exercise outdoors in natural environments, they do so for longer periods of time and at greater intensities.
- Positive health effects are enhanced when green space includes the presence of water, or blue space.

There is also strong evidence that time spent in nature can improve the attention capacity of children with attention deficit disorders. Similarly, some research shows that inner-city children who grow up in public housing buildings with a view of nature have greater impulse control and are able to concentrate better and delay gratification longer.

This report summarizes some of the most prominent research related to nature and public health to help urban natural resource professionals, urban planners, architects, educators, health professionals, and community groups effectively communicate the health benefits of urban nature to their constituents.

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Hospital patients with nature views from their rooms spent fewer days in the hospital and used fewer pain medications.

Some may argue that the observational nature of much of the existing research limits its utility to influence practice and policy–that randomized clinical trials, the gold standard for evaluating health outcomes, are needed to prove a causal link between nature and certain health effects (see Box 1).

We provide this overview of the current literature to describe what we *do* know; which, taken as a whole, offers a compelling case for maintaining and expanding nature-based outdoor environments in cities and bringing people closer to nature. We describe limitations of this research, and we maintain that there are many opportunities to use this scientific knowledge to help improve individual and community health. The pace of nature-health research is expanding dramatically, and increased funding is supporting further study and new approaches to experimental design that will provide even more tangible evidence for the connection between the natural environment and human well-being.

Defining Nature and Health Research

Nature and health research is highly diverse in terms of the human populations studied, types of nature (e.g., tree canopy, parks, or green streets), landscape scales, and health outcomes. This report is organized into reviews of research conducted in five general health categories:

1. Pollution and physical health
2. Active living
3. Mental health
4. Stress reduction
5. Social health, cohesion, and resilience

Engaging with nature can bring about multiple health effects that occur simultaneously and across short or long periods of time. When people exercise in a natural setting, for example, they experience the physical health benefits of active living, while also reducing stress and perhaps alleviating anxiety. They might exercise with family or interact with neighbors along the way, receiving the added health benefits of social connection. They might have a partly negative experience if their asthma or allergy symptoms are exacerbated while out on a day with a particularly high pollen count. In most cases, researchers recognize the multiple connections or associations and acknowledge the difficulty of establishing definitive causal relationships between nature and health. In this report, we categorize each study according to its primary theme to help the nontechnical reader use the information to communicate key findings.

Studies and publications within the nature and health literature contain a range of terminology–nature, parks, gardens, green space, open space, green infrastructure, urban forests, urban ecosystems, metro nature, nearby nature, and other terms–related to the different features and processes that compose the natural environment. In

BOX 1. Studying Health and Nature: Scientific Approaches

Investigative approaches to understanding the connections between human health and nature have evolved over time and are continually being updated, in part due to a desire to move from observational studies to experiments that quantitatively measures relationships between nature and health outcomes—how nature directly and measurably improves public health.

Much of the prevailing social science research has been descriptive, or qualitative, because personal connections to nature are not readily expressed numerically. Early research described responses from people about nature preferences, perceptions, mood, satisfaction with place or neighborhood, and potential behavior. More recent quantitative or measured "nature and health" findings are largely correlational. They confirm a relationship between nature experience and measured health outcomes, but they don't answer a key question—*why do we see such responses*?

Understanding underlying causal mechanisms requires experimental studies where we have a control group (not exposed to nature) and an experimental group (exposed to nature) living under similar conditions and then monitoring health responses over a long period of time. As you can imagine, this can bring up many complex issues such as exposing individuals purposefully to potential unhealthy situations. Setting up a large-scale study and controlling for the variability in human populations can be difficult and costly. Nonetheless, the limited number of quantitative studies that have been conducted have demonstrated significant effects on human health and well-being (Faber Taylor and Kuo 2009, Faber Taylor and others 2001b, Li and Sullivan 2016).

New interdisciplinary research collaborations among the environmental, medical, and public health fields are providing opportunities for experimental science. In Louisville, KY, for example, the Nature Conservancy has teamed with the University of Louisville School of Medicine, Division of Cardiology to conduct the Louisville Green Heart Study. The Conservancy will work with communities to plant trees and other vegetation while university researchers will conduct a longitudinal study to determine the health effects of the neighborhood greening (The Nature Conservancy 2016).

Similarly, advances in technology and the availability of open data sources have enabled correlation or relationships analysis that combines vegetation data layers, urban land use maps, and large-scale health data sets—such as county-level health records or large population health surveys—to examine how changes in vegetation may influence human health.

What's next? Some of the most interesting contemporary research is probing neuroscience, endocrine, and physiological responses to nature exposure. A significant set of questions that are now queued up by the science community concern dosage—how much nature, how often, what kind; and does any of this vary for people across the human lifecycle?

Most of the research reported here explores health outcomes from visual stimulus; scientific investigations are now exploring the influence of other sensory inputs—sound, smell, ambient temperature, and body sensation—on health response. And while less prominent across the decades, qualitative studies of place, meaning, and social interactions continue to reveal human's need to connect with nature for our health and wellness.

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The interdisciplinary Green Heart Study in Louisville, KY, is looking at the effects of neighborhood greening.

most cases, the location and scale of the research study defines the terminology used. Some studies may use remote sensing data to provide measures of natural land cover and human land use features over cities, regions, or countries. Others focus on proximity to a park, the presence of trees lining streets, or even potted plants in office environments. Throughout this publication, we try to maintain the terminology used by the researchers in the referenced study.

There are limitations to the research presented here. A large number of studies described in this review have been replicated multiple times with consistent findings. Other studies are singular, showing interesting results that should not be generalized beyond the specific population, location, and scale of the study. It is important to interpret research findings within their original scope and context.

Pollution and Physical Health

Urban trees and other natural systems provide a range of physical health benefits. Trees can improve air and water quality, mitigate the heat island effect, and help alleviate noise (Nowak and others 2010). Trees can shield people from ultraviolet (UV) radiation, the cause or contributing factor for three types of skin cancer (Nowak and Heisler 2010). Urban ecosystems are increasingly recommended by national and State environmental protection agencies to mitigate the harmful impacts of air and water pollutants, harmful emissions, and the negative effects of urban heat and noise (Wolf and Robbins 2015).

Air Quality

Particulate matter, sulphur dioxide, ground-level ozone, nitrogen dioxide, and carbon monoxide are common air pollutants. Excess air pollution can lead to airway inflammation and reduced lung function. Pollution can also worsen health problems such as asthma, chronic obstructive pulmonary disease, and cardiovascular disease (Shah and Balkhair 2011). Trees and vegetation in parks can help reduce air pollution directly by removing pollutants and reducing air temperature, both of which contribute to smog, and indirectly by reducing energy needs for cooling in surrounding buildings and associated pollutant emissions from power plants (Nowak and Heisler 2010).

The effect of vegetation on urban air quality depends on the vegetation itself, its position on the site, and overall landscape design, as well as the level of air pollution in the area. Since pollution is more concentrated at the source, vegetation should be planted close to the source. A recent review determined that vegetation should preferably be low and/or close to roads to reduce sediment and dust, for example (Janhäll 2015). The review also found that vegetation should be dense but allow airflow to pass through to increase deposition of coarse and ultra-fine particles on leaves; vegetation with "hairy" leaves and a large leaf area were ideal (Janhäll 2015). In a study conducted in Norway and Poland, species such as Scotch pine (*Pinus sylvestris*), Yew (*Taxus media*) and Silver birch (*Betula pendula*) were efficient species in capturing ultrafine particulate matter (Saebo and others 2012).

Vegetation can also *increase* pollutants by emitting volatile organic compounds (VOCs) that can contribute to ozone and carbon monoxide formation. VOC emissions are temperature dependent. Because trees generally lower air temperatures, increased tree cover can lower overall VOC emissions and subsequent ozone levels in urban areas (Nowak 2002). VOC emissions vary by species. Researchers with the U.S. Department of Agriculture, Forest Service have identified nine genera that have the highest emission rates: beefwood (*Casuarina* spp.), *Eucalyptus* spp., sweetgum (*Liquidambar* spp.), black gum (*Nyssa* spp.), sycamore (*Platanus* spp.), poplar (*Populus* spp.), oak (*Quercus* spp.), black locust (*Robinia* spp.), and willow (*Salix* spp.) (Nowak 2002). However, due to the high degree of uncertainty in atmospheric modeling, it is not clear whether ozone formation from VOC emissions for these species is greater than ozone removal or prevention.

Street trees in particular can trap pollutants beneath their canopies or act as a barrier to the natural flow of air through the built environment of cities (Whitlow and others 2011). A number of researchers from Cornell University are developing models to guide the design and layout of tree plantings in urban settings. A recent paper published by the researchers recommends planting trees near solid barriers to reduce downwind pollutant concentrations and using wide vegetation barriers with trees of high leaf area density (Tong and others 2016).

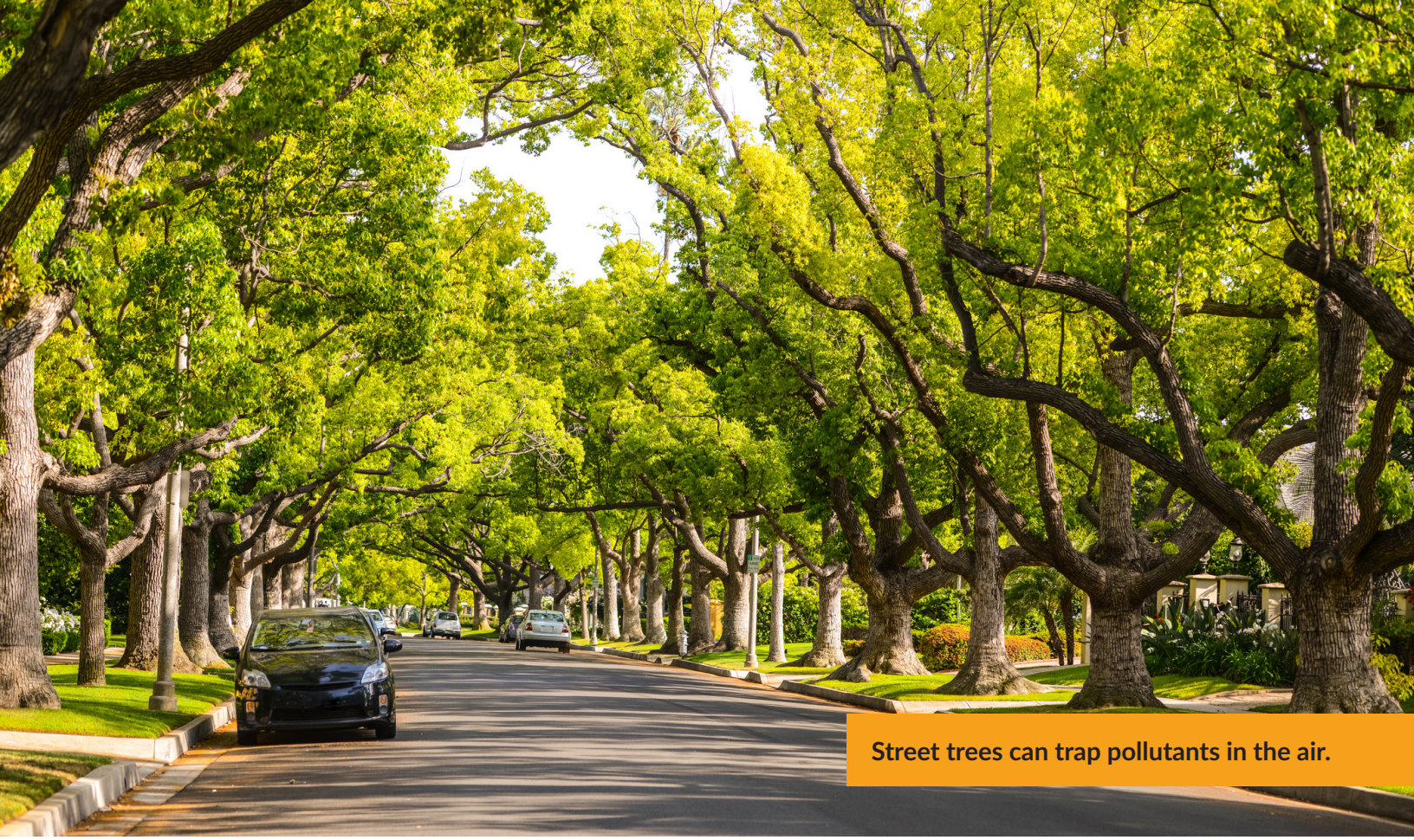
Air quality benefits provided by green space are particularly relevant for human health due to the relationship between air pollution and respiratory illnesses. Nowak and others (2014) found that in 2010, trees removed 17.4 million tons of air pollution across the United States, which prevented 850 human deaths and 670,000 cases of acute respiratory symptoms.

An important issue in urban forestry is the selection and distribution of trees for low allergy impact. Male pollen-producing trees are often planted to minimize unwanted fruit fall. Tree diversity in an urban area is often desired, as concentrations of one species can create heavy pollen source areas (Cariñanos and Casares-Porcel 2011).

Urban Heat

While the relationship between urban green space and air pollution is complex and less certain (Tong and others 2016, Whitlow and others 2011), the cooling effects of green space are more direct and easily measured.

Cities are generally warmer than surrounding agricultural and forested areas due to the dominance of impervious surfaces and energy-absorbing materials, a phenomenon often described as the urban heat island effect. Heat has direct effects on human health, with consistent associations found between increased daily



Street trees can trap pollutants in the air.

Photo by: anouchka, iStockphoto.com

temperatures and increased heat-related deaths, illnesses, and hospitalizations, particularly during extreme heat periods in summer (Vutcovici and others 2014). Children and the elderly are particularly vulnerable. Heat-related illnesses range from mild symptoms of fatigue and heat-stroke to the worsening of preexisting illnesses, hypotension, and death (Harlan and others 2006).

In Phoenix, AZ, heat regularly reaches dangerous levels, making the cooling effects of green space a valuable service. In addition, researchers found that lower socioeconomic and ethnic minority groups in Phoenix were more likely to live in warmer neighborhoods with greater exposure to heat stress (Harlan and others 2006). High settlement density, sparse vegetation, and a lack of green space were significantly correlated with higher temperatures (Harlan and others 2006).

Urban trees are particularly vital for reducing heat stress and decreasing the size and effect of the urban heat island (Zupancic and others 2015). Trees have the unique ability to provide micro-cooling through evapotranspiration, as well as relief from heat stress through shade. Both small and large areas of green space can provide cool islands within cities. Geographic location and the type of available vegetation can also influence the extent that green spaces mitigate the urban heat island effect. For example, green spaces that are connected and closely spaced can improve the flow of cool air through the city (Zupancic and others 2015).

Additional studies have found that urban forests and green roofs can help reduce urban heat island effects (Takebayashi and Moriyama 2007). A recent review (Zupancic and others 2015) examined various types and scales of green space and found that green space can provide cooler air at the park, neighborhood, and city level. Every 10 percent increase in overall urban tree canopy generates a 2 °F (0.6 °C) reduction in ambient heat (Wolf 2008a).

A study of air temperature across the city of Baltimore, MD, looked at air temperature differences in relation to parks and other green space (Heisler and others 2007). When researchers compared temperature points, they found that the center of the city was consistently the warmest, while parks were generally cooler than surrounding areas. Patapsco Valley State Park, which is heavily forested (68 percent tree cover), was the "coolest" of the Baltimore parks, 13 °F (7.2 °C) cooler in the evening and about 5 °F (2.8 °C) cooler in daytime relative to the warm inner city.

Studies show that park temperatures are strongly influenced by the park's vegetation and surrounding land cover,

but also that parks can influence nearby temperatures, sometimes for a distance as great as the diameter of the park (Nowak and Heisler 2010).

Human Mortality

The research community is studying the connection between nature and human mortality, but it is still difficult to draw a causal link. A number of studies describe lack of access to nature and associations with disease, such as cardiovascular disease, and high mortality rates.

A relationship between trees and human health is demonstrated dramatically by the loss of ash trees, many formerly lining city streets, to emerald ash borer. The emerald ash borer, an exotic beetle, was first detected in 2002 in Canton, MI, and then rapidly spread across the Midwest and into Canada. The pest then began to appear in more distant locations as infested trees were unknowingly shipped as firewood. Within 4 years of detection, over 100 million ash trees died. Their disappearance meant that many parks and neighborhoods, once tree-lined, were now bare.

This widespread tree mortality served as a natural experiment. Researchers looking at human health statistics for counties affected by the emerald ash borer found increased human mortality rates, with a large spike in people dying of cardiovascular and lower respiratory tract illness (Donovan and others 2013). Even after controlling for many socioeconomic factors, such as income and education, the analysis showed the same pattern across counties with very different demographic makeups. While the researchers were not able to explain the cause of the association, they demonstrated that the relationship between trees and human health was undeniably strong.

Active Living

While super-sized sodas, junk food, and all-you-can-eat buffets are often blamed for the obesity epidemic in the United States, another key culprit is a steep decline in the level of physical activity. People in the United States are consuming the same level of daily calories as they did in the late 1980s, but are burning fewer calories in exercise, work, or play. Between 1988 and 2010, the percentage of women who reported not engaging in regular physical activity rose from 19 percent to 52 percent. For men, the number increased from 11 percent to 43 percent (Ladabaum and others 2014).

Fewer people walk or bike to work. Many jobs themselves have become increasingly sedentary. Jobs demanding moderate physical activity, which accounted for 50 percent of all jobs in 1960, have plummeted to just 20 percent (Church and others 2011). Kids are playing outdoors less, and fewer are signing up for team sports (Physical Activity Council 2016). Kids and adults are both spending a great deal of time sitting at school and work and at home in front of screens—televisions, computers, and mobile devices (Rideout and others 2010).

Photo by: DeanDrobot, iStockphoto.com

Fewer people bike to work than in the past.

One result of inactivity is a marked increase in obesity. Rates of childhood obesity have tripled (12–19 years old) or quadrupled (6–11 years old) since the early 1970s, and those of adults have more than doubled (USDA 2010). Obesity places people at increased risk of multiple chronic diseases and conditions: high blood pressure, high cholesterol, type 2 diabetes, coronary heart disease, stroke, gallbladder disease, osteoarthritis, sleep apnea, cancer, and mental illness. The rise in long-term chronic diseases related to obesity results in billions of dollars per year in medical costs and lost productivity (Center for Disease Control and Prevention 2016).

The shift to a sedentary lifestyle has been rapid and costly. Though it's been shown that changes in diet can help, daily moderate activity is key to controlling weight gain. Even 30 minutes of brisk walking 5 days a week can significantly reduce health risks (U.S. Department of Health and Human Services 2008). However, 51 percent of U.S. adults are not meeting the minimum guidelines for aerobic physical activity, and 26 percent are not active at all (Center for Disease Control and Prevention 2015).

The availabity of nearby parks can encourage physical activity.

Photo by: BraunS, iStockphoto.com

Research confirms that the availability of parks, trails, and nature can positively affect attitudes toward being active and encourage physical activity (Wolf 2008b), and shows that when people exercise in natural environments, they do so for longer and at greater intensities (Kerr and others 2012). The following sections provide more information about the beneficial relationships between nature and active living and the features of outdoor environments that promote activity.

Benefits of Physical Activity

While it's widely accepted that physical activity is good for physiological and psychological well-being, different environments influence levels and duration of physical activity differently. People who use parks and open spaces are three times more likely to achieve recommended levels of physical activity than non-users (Giles-Corti and others 2005), and people who exercise outdoors tend to do so for longer periods and more energetically than those who solely exercise indoors (Ceci and Hassmen 1991, Focht 2009).

In one study, a 15-minute stroll through the woods increased participants' attention, positive emotions, "connectedness" to nature, and ability to reflect on a life problem more constructively than a walk through an urban setting did for other participants (Mayer and others 2009).

In a similar study, participants with serious depression received significant cognitive benefits and improvements in mood after a 50-minute walk in a natural setting relative to one in an urban setting (Berman and others 2012).

One of the primary symptoms of depression is rumination, or repetitive thoughts focused on negative features of the self (Bratman and others 2015). Participants who took a 90-minute nature walk reported having less rumination and exhibited decreased neural activity in a part of the brain linked with sadness and self-reflection. These findings led the researchers to recommend investment in access to natural environments in order to improve the "mental capital" of cities and nations (Bratman and others 2015).

Researchers have also started addressing the question of nature "dosage" (Barton and Pretty 2010, Shanahan and others 2015). What types and amounts of nature exposure provide the most benefits? How much is enough? Shanahan and others (2015) have proposed that the nature–health research community consider measuring the quality and quantity (i.e., the intensity) and the frequency and duration of the nature experience, and determine how each of these aspects of the nature dose are likely to be linked to different health outcomes. They propose that future research generate quantifiable nature-based health recommendations.

Features that Promote Physical Activity

We assume that physical activity in outdoor environments is good for physical and psychological health, but that assumption raises a number of other questions. Does the mere presence of nature or green space encourage people to be active? Are there particular features or nature designs that prompt outdoor play or that are better suited to active users? Fortunately, researchers are beginning to address these questions.

Transportation systems in most contemporary cities and towns focus on efficiently moving automobiles, with little consideration of pedestrians, bicyclists, or public transportation. Today, less than 3 percent (2.8 percent) of the U.S. population commutes to work by walking, as opposed to 9.9 percent in 1960, and less than 1 percent (0.5 percent) arrives at work on a bicycle (McKenzie 2014). These trends are directly related to the obesity epidemic and lack of physical activity in the United States (Wells and others 2007).

While it may seem intuitive that the availability of green space promotes "active transport" (walking and/or biking as a means of transportation) by making routes to destinations more attractive, the evidence is actually mixed. When it comes to commuting, distance to destination, availability of suitable infrastructure (e.g., sidewalks, bicycle lanes), and safety are more important factors than green space (Heinen and others 2010).

For example, bicycle commuters in Belgium prefer paths that are separated from traffic by vegetation barriers, bioswales, or a shoulder (Ghekiere and others 2014). The same study concluded that parents were more likely to allow children to commute to school by bicycle if the path was separated from the road.

Does the mere availability of parks and green space promote physical activity? Again, the results are mixed. While a number of studies have linked higher levels of physical activity with green space access (Sugiyama and others 2008), other studies have failed to find a significant relationship (Foster and others 2009, Mytton and others 2012). It is difficult to establish a direct link between levels of physical activity and the mere availability of green space (Lee and Maheswaran 2011). It is not a simple case of "build it and they will come."

Other factors may be more important in people's decisions regarding whether to use a given park, trail, or green space for physical activity, such as the presence of infrastructure and amenities, attractiveness, organized park programming (such as group hikes or exercise classes) and maintenance of the grounds, accessibility, and safety (Cohen and others 2009, Owen 2004) (see table 1).

A survey of 1,148 adults living in the U.S. South found that the number of adults who met physical activity guidelines was 15 percent higher in neighborhoods with sidewalks (Reed and others 2006). Similarly, an Atlanta study combining a Geographic Information System land-use study with digital motion trackers found that 37 percent of adults living in high walkability neighborhoods were likely to meet physical activity guidelines, compared to 18 percent of those living in low walkability neighborhoods (Frank and others 2005).

Table 1. Positive Factors for Physical Activity

Physical Environment
Higher population density (city core rather than suburbs); higher housing density
Mix of land uses (such as residential and retail)
Street design with more connectivity
Accessible public transit
Walking and biking infrastructure (such as sidewalks and bike lanes)
Psycho-Social Environment
Safety from crime
Safety from traffic
Absence of social disorder
Aesthetics (including trees and landscape)
Educational campaigns (such as Walk-to-School programs)
Incentive programs (such as workplace reimbursement for transit use)
Park programming (such as exercise classes, group hikes)

Source: Wolf (2008b), Cohen and others (2009).

Perceived safety is an important characteristic and precondition for the use of green space for physical activity (Jansson and others 2013). For children, the safety of the environment as perceived by their parents is a crucial factor in use of a given park or facility (Ferdinand and others 2012).

One component of safety is crime. Research on the relationship between crime and the presence of vegetation indicates that the presence of trees and grass around residences results in less crime than in more barren residential areas (Donovan and Prestemon 2012; Kuo and Sullivan

Residents of easily walkable neighborhoods are more likely to meet physical activity guidelines.

Photo by: jhorrock, iStockphoto.com

2001a, 2001b; Troy and others 2016). In a study covering a rural-urban gradient in and around Baltimore, Troy and others (2011) found that a 10-percent increase in tree canopy was associated with a roughly 12-percent decrease in crime. Kondo and others (2015) examined Philadelphia crime statistics relative to roadside gray areas that had been upgraded with vegetation for mitigating stormwater runoff. They found a significant reduction (18–27 percent) in reports of narcotics possession in areas around the green improvements, compared to an increase of 65 percent across the city during the same period.

Despite the evidence from research, there is a public perception that vegetation provides a screen for criminals to hide behind or conceal their activities. A series of studies on a university campus in the 1990s concluded that areas with more places for concealment or hiding, such as those with more vegetation, elicited more fear and stress responses, and less feelings of safety (Nasar and Jones 1997, Nasar and others 1993). Thus, while the data may generally show less crime in greener areas, the perception of a lack of safety may counteract the actual situation, and undermine the attractiveness of a park or trail for physical activity (Maas and others 2009a).

Crime Prevention through Environmental Design best practices can include urban greening to create more defensible, safer outdoor spaces (Cisneros 1995). Visibility is a key factor in how users rate green space safety (Kaplan and Talbot 1988). Areas with larger trees and more open space are generally deemed safer than areas with dense vegetation, small trees, and large shrubs (Koskela and Pain 2000). Greater openness is perceived as less dangerous. Managers may want to consider public safety perceptions when designing and maintaining urban parks, green space, and trails in order to create more welcoming, well-used spaces that deter crime and create safer and more active communities. A recent study on neighborhood crime in Baltimore supports intentional landscape design and maintenance and provides preliminary best practices for deterring criminals. The presence of yard trees, garden hoses, and well-maintained lawns, for example, as well as pruned shrubs and vegetation, are “cues to care” that can reduce crime (Troy and others 2016).

Mental Health

Frederick Law Olmsted, the designer of New York City's Central Park, wrote extensively about the mental health benefits of contact with nature. As early as 1865, he declared that time in nature provided "relief from ordinary cares, change of air and change of habits" and "increases the subsequent capacity for happiness and the means of securing happiness" (Olmstead 1865 [1952]). While Olmstead's claims were based on personal observation and intuition, research is now proving the statement highly insightful.

Researchers are finding that time spent in nature provides a wealth of mental benefits, from increased cognitive performance and well-being (being at your best) to alleviation of mental health illnesses such as depression, attention deficit disorders, and Alzheimer's. In this section we describe some of this research and how green space and parks can be designed and utilized for mental health.

General Mental Health and Happiness

Researchers at the University of Exeter surveyed 10,000 urban residents in the United Kingdom, asking them how satisfied they were with their lives and whether they had signs of depression, anxiety, or other psychological disorders. After controlling for other factors known to significantly influence well-being such as income, employment, marital status, health, and housing, they found that as green space increased within a 2.5-mile radius of residents' homes, overall well-being received a boost as well (White and others 2013). One of the researchers explained the relationship this way: "We know that getting married, for example, decreases depression and increases life satisfaction. And also getting a job when you are unemployed decreases stress and increases life satisfaction. How big were our effects relative to that? Moving from an area of little green space to an area of quite a lot of green space was about a third of the effect of getting married and about a tenth of the effect of moving from unemployed to employed" (University of Exeter 2016).

In an analysis of a public health survey of 11,200 adults, Danish researchers found a 42-percent increase in self-reported stress levels among individuals living more than 1 kilometer (km) away from green space (or blue space at lakes and beaches), and those residing beyond the 1-km range also had the worst scores on other dimensions of general health, vitality, mental health, and bodily pain (Stigsdotter and others 2010).

Cognitive Function and Mental Fatigue

The demands of modern life can often be mentally exhausting. Focusing attention on flows of information and tasks, screening out distractions, and responding to the constant stimuli of commuting, work, school, and family leaves many people feeling drained, with memory loss and reduced capacity for sustained attention (Berto and others 2010). Rachel and Stephen Kaplan's Attention Restoration Theory (ART) suggests that we can use nature to restore depleted cognitive functions and maintain performance (Kaplan 1993, 1995).

ART proposes that our brains switch between two different attention systems, directed and involuntary. Directed attention is what people use at the workplace to solve problems and focus on tasks, all the while negotiating the surrounding distractions that typify many offices or workplace environments. Directed attention also leads to mental fatigue, which is that "drained" feeling that affects our cognitive performance.

Involuntary attention, also called soft fascination, is what our brain uses when our attention is captured by something stimulating or intriguing. Involuntary attention does not require intense focus and involves effortless reflection. ART proposes that this is the type of attention people use in natural environments, which serve as places for mental restoration, as they enable the directed attention system to recover from fatigue.

Photo by: dolphinphoto, iStockphoto.com

The designer of New York City's Central Park (shown here), Frederick Olmstead, wrote extensively about the benefits of regular contact with nature.

ART has been subjected to a number of experiments that appear to support its basic principles (Berman and others 2008, Li and Sullivan 2016, Pilotti and others 2015). In one study, researchers gave participants a tough memory and

attention test. Participants were then assigned to take a 50- to 55-minute walk through either the Ann Arbor Arboretum or downtown Ann Arbor, MI. When the participants returned to the lab and took the test again, the arboretum group scored significantly higher (Berman and others 2008). According to the authors, the results demonstrate the valuable mental benefits provided by time in nature: "Simple and brief interactions with nature can produce marked increases in cognitive control. To consider the availability of nature as merely an amenity fails to recognize the vital importance of nature in effective cognitive functioning."

Photo by: Halfpoint, iStockphoto.com

Walks in nature can improve cognitive brain function.

Most people may not have time to go for a 50-minute walk during the middle of their workday, or have access to a world-class park such as the Ann Arbor Arboretum. However, less immersive contact with nature can provide some of the same benefits. Even brief "nature breaks" can improve brain performance by providing a cognitive reprieve from the complex demands of modern life (Bratman and others 2015, Mantler and Logan 2015, Shibata and Suzuki 2002).

In another study, environmental psychologists in Australia gave test subjects an attention and memory task. In the middle of the test, participants got a 40-second break, during which they looked at simulated external views: some looked at a simulated view of a concrete roof, while others looked at a "green roof" that resembled a flowering meadow (Lee and others 2015). The participants who looked at the green roof performed significantly better on the second half of the test than the others. In a study in Norway, participants who sat at a desk with plants performed better on a memory and attention test than those who sat at an empty desk with no natural stimuli (Raanaas and others 2011). In the case of offices and schools, the addition of natural features could significantly improve attention and content retention rates.

Mental Illness

Contact with nature can also provide relief, and perhaps healing, for those who suffer from short-term and chronic mental illness (Berman and others 2012), including depression, anxiety, and mood disorders.

Public health researchers from the University of Canterbury in New Zealand compared neighborhood green space across Auckland with the New Zealand Ministry of Health Tracker database for treatment of anxiety and mood disorders in the area. Socioeconomic differences between neighborhoods were addressed using a measure of "socioeconomic deprivation" from the New Zealand census (Nutsford and others 2013). The connections were clear. Every 1-percent increase in the proportion of usable or total green space resulted in a 4-percent lower rate of anxiety/mood disorder treatment, and a 3-percent lower treatment rate for every 100-meter decrease in distance to the nearest usable green space.

A population-level study (2,479 individuals) along a rural to urban gradient in Wisconsin compared mental health outcomes with a vegetation index and percentage of tree canopy coverage (Beyer and others 2014). After controlling for a wide variety of socioeconomic factors, the authors identified a strong association between better mental health among both urban and rural residents in areas with more green space. Higher levels of neighborhood green space were associated with significantly lower levels of symptoms for depression, anxiety, and stress. The researchers suggested that, "greening could be a mental health improvement strategy in the United States."

In a series of Dutch studies, researchers found a connection between neighborhood greenness (typically within 1–3 km from a residence), self-reported general health, and a lowered risk of physician-diagnosed diseases. Individuals with small amounts of green space (10 percent) within 1 km of their home had a 25-percent greater risk of depression and a 30-percent greater risk of anxiety disorders in comparison to those with large amounts of green space (90 percent) close to their home (Maas and others 2006, Maas and others 2009c). Interestingly, the relation was stronger for children and people with a lower socioeconomic status, defined according to education level and work status (the researchers did not have access to data on income).

Children and Mental Health

In recent decades, the growing popularity of digital media and technology has changed the relationship between people and nature. For children, more time interacting with digital devices means less time outdoors, less time spent in free play, and less real, first-hand experiences with nature. Books such as *Last Child in the Woods* by Richard Louv have increased awareness of this issue (Louv 2005). Research concludes that our growing disconnect with nature has real and lasting effects; however, it also shows the restorative effects of even limited contact with nature for both children and adults in attention restoration and managing symptoms of attention deficit disorders (Berman and others 2008).

The ability to harness self-discipline, delay gratification, and control impulses has been linked to a range of positive outcomes for kids, including academic success and physical and psychological health. Teenagers who lack impulse control and self-discipline may be at greater risk for delinquency, pregnancy, and drug use (Faber Taylor and others 2001a). Some studies show that contact with nature can help increase self-discipline. Researchers from the Human-Environment Research Laboratory at the University of Illinois, Urbana-Champaign, studied 169 boys and girls who lived in identical, high-rise buildings in an inner city with varying levels of nature nearby. They found that the more natural the view from a participant's home, the higher the participant scored on tests of concentration, impulse inhibition, and delayed gratification (Faber Taylor and others 2001b). The researchers provided this compelling thought: "Perhaps when housing managers and city officials decide to cut budgets for landscaping in inner city areas, they deprive children of more than just an attractive view."

Additional studies from the Human-Environment Research Laboratory at the University of Illinois, Urbana-Champaign, conducted over the past decade revealed strong evidence of nature's benefits for children affected by Attention Deficit Disorder (ADD) and Attention Deficit Hyperactivity Disorder (ADHD) (Faber Taylor and Kuo 2009, Kuo and Faber Taylor 2004). Of note is a study they did that engaged children with ADHD in walks in several different environments. The children who walked in a park showed more improvements in attention after walking in a park than those who took walks in downtown or neighborhood settings. The effect was comparable to those reported for common pharmaceutical therapies for ADHD (Faber Taylor and Kuo 2009). "'Doses of nature' might serve as a safe, inexpensive, widely accessible new tool in the tool kit for managing ADHD symptoms," the researchers concluded.

Photo by: mkovalevskaya, iStockphoto.com

Children are increasingly disconnected with the outdoors.

Children and Academic Success

Nature may also play a role in academic success. Researchers linked remote sensing measures of vegetation cover around 905 elementary schools in Massachusetts with the results of standardized tests. They found that the presence of more trees and vegetation was associated with higher scores on standardized tests (Wu and others 2014). Adjusting their analysis to account for income, researchers found higher scores of children from both low- and high-income areas were correlated with increased vegetation cover.

Another study in Michigan found, after controlling for student socioeconomic status and racial/ethnic makeup, building age, and size of school enrollment, that views from cafeterias and classroom windows with greater quantities of trees and shrub cover were positively associated with elevated standardized test scores, graduation rates, and percentages of students planning to attend a 4-year college, as well as fewer occurrences of criminal behavior (Matsuoka 2010). Li and Sullivan (2016) found classroom views of green landscapes were related to significantly better performance on tests of attention and led to students' more rapid recovery from stressful experiences.

Landscape Design for Mental Health

The "savannah hypothesis" argues that people prefer open landscapes with scattered trees, similar to the African landscapes in which humans evolved (Heerwagen and Orians 1993). New work supports the idea that the psychological benefits of green space are linked to plant species diversity (Williams and Cary 2002). For example, people who spent time in a park with greater plant species

richness scored higher on various measures of psychological well-being than participants who spent time in less biodiverse parks (Fuller and others 2007). The authors suggest that parks and green space should provide a mosaic of habitat patches to support both biodiversity and the well-being of human populations.

Stress Reduction

Stress has become a constant in people's everyday lives—work demands, financial strains, and family pressures. The cumulative effect of chronic stress can have serious health consequences over time, including depression, anxiety, heart disease, high blood pressure, chronic pain, and type 2 diabetes (Collingwood 2013). Researchers in Japan are discovering that surrounding oneself with nature can be one of the most powerful stress relievers available. In fact the practice of "forest bathing" has become a popular way to unwind in Japan and elsewhere (see Box 2).

Getting outside typically involves at least a little exercise, and exercise is a proven mood booster (Aspinall and others 2013, Barton and Pretty 2010). Also, being outside means people are more likely to encounter neighbors and friends, and social contact is another way to reduce stress (Heinrichs and others 2003). Views of natural scenes can effectively reduce stress (Kahn and others 2008), and this is particularly true if initial stress levels are high (Roe and others 2013).

BOX 2. Forest Bathing

Shinrin-yoku is the name given to the Japanese art of "forest bathing." Forest bathing typically involves meditative walks through the woods with the objective of reconnecting with nature, decreasing stress, elevating natural moods, and strengthening the immune system. Forest bathing is rooted in Shinto and Buddhist practices that promote the experience of nature through all five senses. Forest bathers spend time touching and smelling leaves, bark, and flowers. Some even bring essential oils along to enhance smells. Meditation is often part of the experience as well. The practice originated in Japan in the early 1980s when it was endorsed by the Forest Agency of Japan and has since been gaining ground in the United States and other locations around the world.

Since 2004, Yoshifumi Miyazaki, director of the Centre for Environment Health and Field Sciences at Chiba University in Japan, has taken more than 600 research subjects into the woods for monitored forest bathing trips. He and his colleagues have found that forest walks, compared with urban walks, yield a 12.4-percent decrease in the stress hormone cortisol, a 7-percent decrease in sympathetic nerve activity, a 1.4-percent decrease in blood pressure, and a 5.8-percent decrease in heart rate (Lee and others 2009, 2011). On subjective tests, study participants also report better moods and lower anxiety. The lower concentrations of cortisol are a direct indicator of less stress. Overexposure to cortisol and other stress hormones has been linked to increased anxiety, depression, heart disease, weight gain, and focus and concentration difficulties. Overall, forest bathing appears to have significant stress-reduction benefits.

Photo by: Smileu, iStockphoto.com

Forest bathing can help decrease stress, blood pressure, and heart rate.

Stress recovery theory (SRT) is based on empirical studies that demonstrated immediate positive and physical responses to natural settings or even views of nature (Ulrich 1983). When a person is stressed, views of nature can reduce blood pressure, muscle tension, and pulse rate within minutes. SRT suggests that this is an evolutionary reflex associated with the limbic system—one of the oldest parts of the brain and the seat of the emotions—in response to settings that signal safety and an abundance of food. According to SRT, evolution conserved this functional response because more rapid recovery from stress helped early humans to quickly move from one survival task to another. Certain types of settings, such as places with abundant vegetation, calm or slow-moving water, savannah-like locations, and unthreatening wildlife, are more likely to be restorative.

Photo by: shankekala, iStockphoto.com

Natural features near workplaces can provide a place to reduce stress during the workday.

In one of the earliest and most cited studies about stress, Ulrich and others (1991) presented a graphic, 10-minute work accident film to 120 students. Before and after the film, viewers' stress levels were evaluated using measures of blood pressure, muscle tension, and heart rate, along with a self-rating of stress. Next, students watched a 10-minute video of either pristine nature (a peaceful river and forest) or of a congested urban scene filled with traffic and pedestrians. Recovery was faster and more complete for the subjects who were exposed to the nature video. In some cases, participants who viewed nature scenes were even more relaxed than before viewing the accident film.

The stress-reducing quality of nature has also been shown in investigations of cortisol, a hormone released by the adrenal glands in response to stress. In one study, scientists measured the levels of cortisol in 25 socioeconomically disadvantaged adults in Scotland and asked them to fill out questionnaires about what stressed them out at home and at work (Ward Thompson and others 2012). The data were then compared to the number of parks, woodlands, and other natural environments in each participant's zip code. The researchers found that those who lived in areas with the highest amount of green space had lower levels of cortisol, and their self-reported feelings of stress were lower than those who spent more time in urban settings without green space. The authors recognized the limitation of the small sample size, which was used to assess the feasibility of the study protocol.

In an interview with the BBC, Catherine Ward Thompson, the lead researcher on the study, said: "Our whole neuroendocrine system has evolved over millennia to respond positively to environments that are seen as providing what we need to live and thrive. There is something about the natural environment that is biologically part of our system. In a way, we are hard-wired to respond to it . . . and this may be turning our bodies back into something we have evolved biologically to respond positively to" (Kinver 2012).

Research has further clarified how natural areas in urban environments can help buffer people from stress factors. For example, green space between residences and high-traffic roads can reduce nuisance noise levels (Gidlöf-Gunnarsson and Öhrström 2007, Nilsson and Berglund 2006) and vegetation can increase privacy and conceal aesthetically displeasing structures (Smardon 1988). Just the presence of natural features near homes, schools, hospitals, and workplaces appears to be beneficial (see Box 3). Residents of public housing with nearby vegetation may more effectively cope with stress compared to those with homes surrounded by concrete (Kuo 2001).

Medical studies have shown that exposure to stress, especially for prolonged periods, can reduce immune response in humans. Recently, Kuo (2015) proposed enhanced immune functioning as a "central pathway" between nature and health. The author points out that natural environments have physiological and psychological effects related to immune functioning and that the natural world includes chemical and biological agents that boost immune functions (Kuo 2015).

BOX 3. Healing Gardens

Hospital settings are inherently stressful. Stress, anxiety, depression, and post-traumatic stress disorder (PTSD) are documented in many clinical studies on patient and family stress in relation to hospitalization. Even when medical procedures are routine, patients describe stressful feelings. For hospitalized patients requiring more complex treatments for cancer therapies, transplant surgery, stroke rehabilitation, palliative care and more, patients and their families often note high levels of stress.

Legacy Health, a nonprofit operating hospitals in Oregon and SW Washington, has embraced the installation of healing gardens at all of their locations as a way for patients and staff to relax, recover, and rejuvenate. Their first therapeutic garden was built in 1991; there are now 12 gardens at their 8 hospitals.

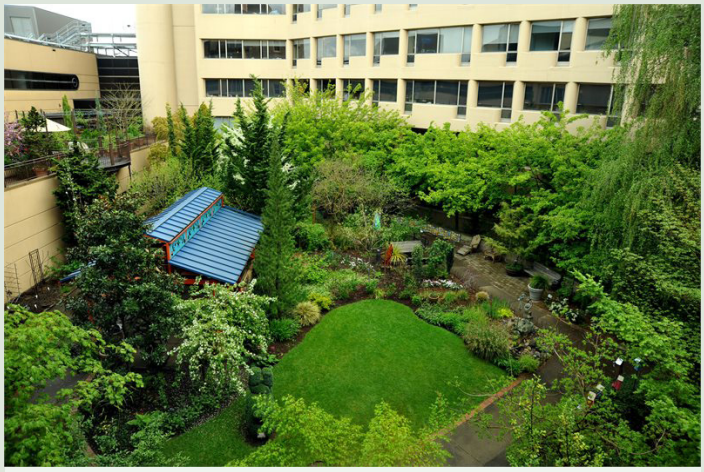


Photo by: Legacy Health

Healing gardens provide a place for patients to reduce stress during hospital stays.

Physicians, nurses, and therapists from a range of practices—psychiatry, physical rehabilitation, pediatrics, trauma, cancer, burn, and family birth centers—prescribe use of the gardens to their patients. Visitors and employees are also encouraged to use the gardens. Behavioral health patients participate in horticulture therapy treatments, and patients from the Children's Hospital engage in weekly nature stations.

Patients and staff report that using the Legacy hospital gardens helps them to relax and rejuvenate, and families of patients say that time spent in restoration in the gardens allows them to be able to better help their loved ones.

Therapeutic gardens:

- **Encourage activity and movement**
- **Help reduce stress**
- **Help build social and emotional support**
- **Provide a wealth of sensory and natural benefits from the sun, wind, rain, breezes, smell of soil, birdsong, trees, shrubs, flowers, butterflies, water sound, hummingbirds, moonlight, and more**

Social Health, Cohesion, and Resilience

Humans are naturally social, but the nature of modern life has decreased the quantity and quality of our social ties. Most people no longer live within extended families, and many live far away from even their closest family members. As Robert Putnam's *Bowling Alone: The Collapse and Revival of American Community* documented, Americans are increasingly isolated and disengaged from traditional institutions and networks such as churches, labor unions, and civic organizations that used to form the basis for their social lives (Putnam 2000).

Americans are far more socially isolated today than they were two decades ago, and a sharply growing number of people say they have no close friends (McPherson and others 2006). Similar to physical activity, social relationships are important for health and well-being. For example, lack of strong social relationships has been directly linked to the development and progression of cardiovascular disease (Knox and Uvnas-Moberg 1998) and health-threatening behaviors such as smoking, drinking, gang involvement, and drug use (Cubbin and others 2008).

Generally, research has shown a positive relationship between social ties and cohesion and green space (de Vries and others 2013, Francis and others 2012, Maas and others 2009b). Perceptions of social coherence and the extent and depth of local social interactions can be associated with perceptions of the greenness of the neighborhood (Sugiyama and others 2008). Of course, the type of green space matters. A 2013 study found a similar relationship

between green space and perceptions of social cohesion, but the researchers determined that the quality of the green space—measured in terms of variety of plants, maintenance, orderly arrangement, absence of litter, and general impression—mattered more than the quantity of green space in promoting social cohesion in the neighborhood (de Vries and others 2013).

Green, or nature-based, infrastructure builds physical resilience in a community and is key to mitigating natural disasters. Effective urban forestry programs and active environmental stewardship networks can provide the leadership to respond to and recover from natural disasters (Tidball and Krasny 2013). Erika Svendsen and Lindsay Campbell of the Forest Service's New York City Field Station research the relationship between environmental stewardship, healing, and community resilience in the aftermath of disasters (Svendsen and others 2014). They have documented how communities in New York City created "living memorials," or green space dedicated to memorializing the lives lost in the 9/11 attacks (Svendsen and Campbell 2010). The same authors looked at the role of nature in the rebuilding effort that took place in Joplin, MO, after the devastating 2011 tornado that completely destroyed much of the town and killed 161 people (Svendsen and others 2014). They found that as volunteers and community groups become actively involved in the stewardship of natural resources, their communities show increased civic engagement and ecological literacy. Additionally, communities that work together to create green infrastructure designed to be resilient to storms and other disasters can also generate and nurture social connections in these shared places.

Social Cohesion and the Elderly

Walkable green space is associated with greater longevity in older people (Takano and others 2002), and this is likely connected to the increased social interaction that is often associated with outdoor time for elderly individuals. For the elderly, increased social interaction is correlated with lower rates of mortality, depression, and cognitive impairment (Almedom 2005, Lubben 1988, Maas and others 2006). These studies highlight the importance of having accessible parks, gardens, and green space in close proximity to neighborhoods with large numbers of elderly residents as well as care centers.

Community gardens can improve nutrition, increase physical activity, and provide a location to socialize with neighbors. Community gardens can also provide a source of fresh fruits and vegetables often not readily available. Alaimo and others (2008) found that adults were 3.5 times more likely to consume at least five servings of fruit or vegetables a day if someone in their household participated in a community gardening project within the last 12 months. Studies show a range of mental health benefits from gardening as well: reductions in the severity of depression, increased attention (Gonazalez 2010), and prevention of the onset of dementia and negative dementia behaviors and symptoms (Fabrigoule and others 1995, Simmons and others 2006).

Photo by: laflor, iStockphoto.com

Community gardens are a great way for seniors to get physically active outdoors.

Alzheimer's disease is one of a number of cognitive impairments, collectively termed dementia, that primarily affect older individuals. Dementia patients with access to therapeutic or outdoor gardens exhibit fewer disruptive or agitated behaviors (Ellis 1995, Mather and others 1997). Time spent in parks and gardens can improve quality of life and function of dementia patients by reducing negative behaviors up to 19 percent, improving sleep patterns and improving hormone balance (Chalfont and Rodiek 2005, Mooney and Nicell 1992). Gardening appears to be particularly effective, improving mobility and dexterity, increasing confidence, and improving social skills among dementia patients (Rappe 2005, Ulrich 2002).

"Wander gardens" are confined outdoor spaces that enable activity without restraint but prevent departure. Access to these spaces is associated with improvements in the mobility of elderly patients (Detweiler and others 2012). At a dementia facility in Virginia, Detweiler and others

(2009) found that patients with access to a wander garden had about 30 percent fewer falls and a reduction in fall severity. In addition, they found significant reductions in the amount of medications used (a 10.5-percent reduction overall, with a range of 3.4 to 22.2 percent).

Social Equity and Access to Nature

Many people, because of lack of access, transportation, or general familiarity, visit parks and green space rarely or not at all (Blanck and others 2012). Physical activity and frequency of park use depend on demographic, socioeconomic, and regional characteristics and reflect inequalities in park distribution (Sister and others 2010) or in the accessibility of parks and green space (Comber and others 2008).

While we note the mixed findings on access to green space in diverse communities (Troy and others 2007), a number of studies have concluded that the distribution of urban green space is related to measures of socioeconomic status, such as income, education, race/ethnicity, and occupation, and regularly report that neighborhoods with higher socioeconomic status enjoy greater access to nearby green space (Gordon-Larsen and others 2006, Jennings and Johnson Gaither 2015, Martin and others 2004, Wen and others 2013). The lack of recreational facilities and green space in low-income communities is associated with decreased physical activity and increased obesity, both of which place people at higher risk for mortality (Mitchell and Popham 2008). Efforts to address physical inactivity and other health concerns related to inequitable access to green space would benefit from analyzing how green spaces are distributed throughout diverse populations (Jennings and others 2012).

Equal access to nature seems to help remediate some health disparities between low- and high-income neighborhoods. Several studies have found that limited access to green space in low-income neighborhoods can negatively affect cardiovascular health, in comparison to wealthy neighborhoods (Jennings and Johnson Gaither 2015). However, low-income neighborhoods with large amounts of green space have cardiovascular mortality rates similar to those of wealthy neighborhoods (Mitchell and Popham 2008).

Access to green space can also reduce other health conditions such as obesity, psychological health, and heat-related illness (Jennings and Johnson Gaither 2015). For example, higher tree density in urban areas is associated with decreased risk of childhood obesity (Lovasi and others 2013) as well as depression and type 2 diabetes (Astell-Burt and others 2014) among low-income urban families.

Studies also document how green space play a role in reducing stress. By monitoring patterns of salivary cortisol (a biological indicator of stress), a study in low-income areas of Dundee, Scotland, reported healthier daytime salivary cortisol patterns and lower levels of perceived stress for residents with higher proportions (more than 43 percent) of green space (Roe and others 2013).

Low-income communities typically have fewer resources to help them deal with pollution, fewer municipal services to mitigate the effects of pollution, and fewer resources at the household level to buffer families from the effects of pollution. Therefore, poorer communities are at a higher risk of exposure to air pollution and the effects of extreme heat (Huang and others 2011, Jesdale and others 2013). Since chronic health conditions can disproportionately affect low-income communities (Marmot and Allen 2014), limited access to the benefits from green space is a particularly important issue for vulnerable populations.

Photo by: Willard, iStockphoto.com

Rural communities face different barriers to active living than those in urban areas. They often and have limited access to recreation and physical activity opportunities.

While much of the discussion of the connection between green space and health focuses on urban environments, rural children and adults have higher rates

of obesity than their urban counterparts, and the barriers to active living in rural areas are often much different than the challenges of increasing physical activity in urban areas (Yousefian Hansen and Hartley 2015). Rural communities often lack transportation options and have limited access to recreation and physical activity opportunities. Other barriers may include isolation, climate and terrain, cost and safety fears such as high traffic speeds, the threat of loose dogs and wild animals, crime concerns, and lack of sidewalks and lighting (Yousefian Hansen and Hartley 2015).

Conclusion

People are dependent on nature for food, water, security, health, and well-being—we are connected with the natural world for our very survival. Green spaces also make us happier and healthier. The evidence of the link between nature, health, and preventive medicine will hopefully spur more direct collaboration between the health, urban planning, education, and natural resource communities. With the growing pressures of modern life, these are critical connections to pursue; the answers to some of the biggest challenges facing these groups lie in the recognition of shared interests, goals, and objectives. This area of research will continue to grow in the coming years and decades, illuminating the essential role that nature plays in the health and well-being of our minds, bodies, and spirit.

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