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## GREENING CITIES IN AN URBANIZING AGE

The Human Health Bases in the Nineteenth and Early Twenty-first Centuries

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Figure 1. Expressions of urban greening in the nineteenth and early twenty-first centuries. Image on top: Birds-eye view of Central Park in New York City, N.Y., 2005. (William Scherer [WilliamSchererPhotography.com]). Image on bottom: Simulated illustration of urban greening in Philadelphia, Pennsylvania, 2011. (Philadelphia Water Department. Rendering by Wallace, Roberts and Todd)

Defined here as the introduction or conservation of outdoor vegetation in cities, urban greening has bloomed during periods of intensive urbanization. This was true in the nineteenth century and it seems to be the case again today, as a range of greening practices is co-arising during a third, and perhaps final, period of global urbanization. Human health has been a recurring theme underlying the enduring aspiration to integrate nature with city. Using change over time as a conceptual frame, this paper offers a comparative assessment of municipal greening in the nineteenth and early twenty-first centuries, focusing on the potential implications upon, and the relationship between, such activity, urban design, and public health. In so doing, the narrative bridges theory, science, and practice, and dovetails with discourse on urban ecosystem services. Part one assesses prominent drivers and types of greening in nineteenth-century industrial cities, a pioneering period in this evolving narrative. Part two reviews contemporary literature on the human health benefits of urban green spaces, and draws comparisons to the Industrial Era. Part three explores potential links between contemporary greening practice and scholarship on related health benefits, wherein proximal greening emerges as a distinct form, and possible norm, for twenty-first-century urban design.

## Introduction

Since the rise of urban civilization, vegetated public space has been a strategy to enhance the experience of living in cities. Mesopotamian ruler Sennacherib is said to have dedicated a park to the citizens of Ninevah,<sup>1</sup> and trees were planted in central gathering places during the Greco-Roman era.<sup>2</sup> Amid European and North American urbanization in the Industrial Revolution, reform-minded leaders sought to improve cities through street tree planting and creation of large parks, parkways, and park systems.<sup>3</sup> Today, the world is undergoing a third and in all likelihood final period of urbanization concentrated in Africa and Asia,<sup>4</sup> and a bloom of policies and practices that seek to vegetate the urban fabric is emerging in cities around the world.<sup>5</sup> This contemporary era of urban greening—defined here as the introduction or conservation of outdoor vegetation in cities—may be unlike anything since the nineteenth century.

The enduring aspiration to integrate nature with city is associated with a range of motivations, including political, ecological, aesthetic, and design goals. One recurring premise is that natural landscapes support human health and well-being, an association articulated in the Hippocratic corpus that stressed the importance of climate, water quality, and a scenic environment for health.<sup>6</sup> Public health was, in turn, an important driver of the nineteenth-century urban parks movement.<sup>7</sup> As humanity's migration toward large concentrated settlements now culminates in the "first urban century,"<sup>8</sup> the relationship between public health and the physical design of cities is a subject of substantial interest.<sup>9</sup>

Within this conversation, the human health benefit of urban green space is a growing body of scholarship.<sup>10</sup>

The co-emergence of greening interest and periods of intensive urbanization is noteworthy, and provides an opportunity to assess historical similarities and differences. Using change over time as a conceptual frame, this paper offers a comparative assessment of municipal greening in the nineteenth and early twenty-first centuries, focusing on the potential implications upon, and the relationship between, such activity, urban design, and human health. These periods are meaningful bookends: the medical community had greater influence on the physical shape of cities during the nineteenth century than at any other time in America's history;<sup>11</sup> the vast majority of scholarly research on human health benefits of nature contact has emerged in the past two decades;<sup>12</sup> and these two periods represent significant chapters in the arc of global urbanization.<sup>13</sup>

In so doing, this paper bridges theory, science, and practice, and dovetails with discourse on ecosystem services—the human health and well-being benefits people derive from ecosystems.<sup>14</sup> The author acknowledges that each of these topics could stand as a discrete inquiry, and the synoptic approach contained here is intended as an exploratory investigation that may prompt further discussion. He also recognizes the inherent gap between signifiers and the signified. In cities, terms such as “greenspace,” “green infrastructure,” and “nature” connote elements of varying size, shape, biotic/abiotic components, and vegetation density, as well as ground-level, elevated, and vertical surfaces.<sup>15</sup> This real-world heterogeneity illustrates the limits of language and signifiers such as those offered above. Yet, vegetation is the defining characteristic of green space and green spaces;<sup>16</sup> and these terms are here used synonymously with flora, greenery, and plant material. Furthermore, human health is understood to encompass well-being, and not merely the absence of disease or infirmity, as articulated by the World Health Organization.<sup>17</sup> The paper focuses primarily on greening in the public realm of cities. As such, community and therapeutic gardens—both of which confer human health benefits—are not directly addressed.<sup>18</sup>

Part one examines prominent drivers, associated theories, and principle types of greening in nineteenth-century industrial cities, a pioneering era in this evolving narrative. The section skews toward American examples, in part because noteworthy theoretical and design innovations emerged from this place during the period in question,<sup>19</sup> and the young nation showed remarkable interest in public parks during the late nineteenth century.<sup>20</sup> Part two reviews contemporary literature on the human health benefits of urban green spaces, and draws brief comparisons to the Industrial Era. This is a fast-growing literature, and the overview contained here is not intended to be comprehensive. Rather, the objective is to provide a high-level summary and to situate findings in historic context.

Part three explores potential links between contemporary urban greening practice and research on nature contact and human health. It does so in acknowledgment of limitations regarding extension of findings to landscape and urban design,<sup>21</sup> while recognizing that urban greening is a social practice that may be implemented with or without consultation of said literature. As such, this section offers a preliminary inquiry linking research

with current practice, and it casts an eye toward potential greening strategies that respond to twenty-first-century challenges and opportunities.

## **Urban Greening and Human Health in the Nineteenth Century**

In the late eighteenth century, Great Britain initiated an economic transition from manual labor and draft animals toward machine-based manufacturing, greatly augmenting production capacity and transportation of goods and people. This technological innovation spawned the prodigious growth of cities, as manufacturing and labor agglomerated near urban centers. Between 1800 and 1850, Paris doubled in population from a half million to over one million.<sup>22</sup> In the United States, 5 percent of some four million people lived in cities in 1790; by 1920 the nation had grown to 106 million and the majority lived in cities.<sup>23</sup> The industrial era spurred advancements in human health and prosperity,<sup>24</sup> but overcrowding, filthy water, and inadequate sanitation, storm drainage, and garbage collection were associated with higher mortality rates in urban than rural areas. Indeed, populations of cities during this period grew only because of rapid rural to urban migration.<sup>25</sup> Cities in the United States were also characterized by tenement housing with little fresh air or light, hazardous and unethical working conditions, and extreme income disparities. These conditions inspired an era of progressive social reform and “townsite consciousness,” including sanitary improvements and a heightened sensitivity to the health characteristics of urban settings.<sup>26</sup>

### **Public Parks, Parkways, and Park Systems**

A prominent expression of environmental intervention during the nineteenth century was the urban parks movement.<sup>27</sup> In both Europe and the United States, the ideology of the public park was predicated on the importance of open, public green spaces to the health and vitality of urban populations. A major outbreak of cholera in England inspired a Select Committee on Public Walks to urge Parliament in 1833 to promulgate a law requiring every town to build a park.<sup>28</sup> Likewise, the American Medical Association’s Committee on Public Hygiene argued in 1849 for public squares ornamented with trees to correct the “vitiating” air of industrial cities.<sup>29</sup>

This logic reflected the prevailing miasma theory of disease.<sup>30</sup> Popularized in the Middle Ages, miasma theory held that diseases such as cholera, chlamydia, and Black Death were caused by noxious air. This was disproved in 1854 when British physician John Snow traced an outbreak of cholera in London to a polluted water well, a discovery that is considered the beginning of the science of epidemiology and of modern germ theory, where the mechanism of disease transport is through pathogenic microorganisms.<sup>31</sup> By the 1880s miasma theory had been mostly discredited by the medical profession, although it was embraced by laypeople through the 1890s.<sup>32</sup>

As noted by Kunstler, plant respiration may have been no better understood in the mid-nineteenth century than the germ theory of disease, and it is possible that miasma theory informed the metaphor of urban parks as “lungs of the city.”<sup>33</sup> This adage has been traced to mid-eighteenth-century England, where urban and peri-urban parks were labeled

“the Lungs of London,” establishing a popular analogy that has been employed to advocate for municipal parks worldwide.<sup>34</sup> Reflecting the prevailing sentiment of the medical community in the mid-nineteenth century,<sup>35</sup> Frederick Law Olmsted, Sr., and Calvert Vaux echoed miasmatic reasoning in a descriptive text that accompanied their winning submission to build Central Park in Manhattan, New York. “Two classes of improvements were to be planned for this purpose; one directed to secure pure and wholesome air, to act through the lungs; the other to secure an antithesis of objects of vision to those of the streets and houses which should act remedially, by impressions on the mind and suggestions to the imagination.”<sup>36</sup>

In addition to improved air quality, this passage speaks to another important theme that informed the creation of nineteenth-century urban parks; namely, mitigating the psychosocial disadvantages of urban living. Olmsted was one of the period’s principal advocates, theorists, innovators, and builders of new urban parks, and he would consistently return to this theme. Overexposure to the artificial sights of cities led to “excessive nervous tension, over-anxiety, hasty disposition, impatience, [and] irritability.”<sup>37</sup> By extension, the “restraining and confining” character of city streets compels people to “walk circumspectly, watchfully, jealously . . . [and] to look closely upon others without sympathy.”<sup>38</sup>

To remedy these urban disamenities, Olmsted and his contemporaries drew upon eighteenth-century English landscape garden theories based upon multisensory engagement with natural landscape as a therapeutic means of restoration from physical and mental exertion, as well as from illness.<sup>39</sup> Of particular interest was the link between aesthetics and emotions, and the “unconscious influence” that scenes of picturesque or pastoral beauty affected on the “whole human organism.”<sup>40</sup> This built upon a similar design language developed in the landscapes of rural cemeteries and asylums in the early to mid-nineteenth century, as well as thinking associated with moral therapy, which stressed the capability of patients to recover lost reason through self-control, useful labor, recreation in pleasant settings, and a benevolent, family-like atmosphere.<sup>41</sup> Hartig et al. note that moral therapy proved at the time to be a relatively humane—and thus moral—approach to caring for the mentally ill, who had previously received harsh treatment.<sup>42</sup>

In Europe, parks have been associated with a desire to improve the physical condition of citizens through physical exercise, thus strengthening national defense through their labor or as soldiers.<sup>43</sup> American parks, by contrast, were conceived for leisure and passive recreation.<sup>44</sup> But notwithstanding such cases as Fairmount Park in Philadelphia, where large tracts of upstream land were conserved to protect drinking water,<sup>45</sup> improved air quality and mental well-being were arguably the prominent human health bases for nineteenth-century urban parks. Miasma theory undergirded the former; while English landscape theory and moral therapy informed the latter. These combined logics support depiction of nineteenth-century green spaces as therapeutic landscapes.<sup>46</sup>

Scholars have assessed the characteristics of these parks quite comprehensively.<sup>47</sup> To avoid retreading well-covered terrain, five noteworthy traits of these urban green spaces stand out for purposes of the conversation at hand. One characteristic is their *large size*,

as exemplified by Bois de Boulogne in Paris<sup>48</sup> and Prospect Park in New York City.<sup>49</sup> Another feature is *connectivity* via a system of parkways and linked parks, as exemplified in Boston's Emerald Necklace and in Buffalo, New York.<sup>50</sup> This combination of size and connectivity reflects an emerging awareness of parks as an important *element of comprehensive planning* that can guide the spatial dimension of urban growth.<sup>51</sup>

Two other important features of the urban parks movement pertain directly to human use. Reflecting a rising tide of democratic values, nineteenth-century European cities opened up royal gardens and peri-urban hunting forests that were previously limited to the aristocracy and nobility.<sup>52</sup> But for the first time during this period, urban parks were *systematically created for public use*. This reflected a new form of governance, where access to urban green space expanded from a small cluster of nobles to the bourgeois elite, upper middle class, and finally to the middle and lower working classes.<sup>53</sup> Indeed, urban parks were framed as important elements in creating a more democratic and equitable social order,<sup>54</sup> fostering in the words of A. J. Downing, "an easy and agreeable intercourse of all classes."<sup>55</sup> This sociopolitical logic was, however, not necessarily linked with human health.

Finally, these public spaces mostly adhered to an English landscape design aesthetic known as the picturesque: the pastoral middle landscape between wilderness and city characterized by meadows, open water, woodlands, copses of trees, and gently curving paths.<sup>56</sup> The visual experience of landscape was especially important, yielding *naturalistic scenes* that were highly choreographed and anything but "natural."<sup>57</sup> The deceptively natural vistas and ponds of Central Park, for example, required 114 miles of drainage pipe and moving five million cubic yards of earth and rock.<sup>58</sup> Yet people can still enjoy and benefit from constructed spaces that are representations of natural environments, while knowing of their artificial character.<sup>59</sup>

### Street Trees

Another form of urban greening that gained significant traction during the nineteenth century was street tree planting, but this has received relatively little attention in scholarly discourse.<sup>60</sup> In *City Trees: A Historical Geography from the Renaissance Through the Nineteenth Century* (2006), Henry Lawrence has conducted a comprehensive history on this topic. Notwithstanding precursors such as tree planting along canals of Dutch towns as early as 1597, he finds that systematic planting of trees in the public realm of cities did not become common practice until the nineteenth century, at which point it became a "model for the world."<sup>61</sup> He identifies three principal rationales for planting trees in cities during the 400-year period of his inquiry: expressions of political power, national tradition, and aesthetics.<sup>62</sup>

Focusing on one particular tree, Campanella describes how American elm (*Ulmus americana*) planting emerged as a formal municipal enterprise in the late nineteenth century, transforming the fabric of American New England towns before the tree succumbed to massive die-off in the mid-twentieth century due to Dutch elm disease. Here, civic improvement and beautification are highlighted as underlying motivations for elm tree



Figure 2. Elm Arcade View of the Green, New Haven, Connecticut, ca. 1870. Artist John Filmer. Woodcut. (Yale University Art Gallery. Gift of the Rev. Anson Phelps Stokes, B.A. 1896, M.A. [Hon.] 1900, L.L.D. 1921)

planting (see Fig. 1). He further describes this emerging urban forest as “a democratic project,”<sup>63</sup> reflecting the move toward enlightened governance that also informed urban parks. Addressing the history of urban forestry in Europe, Konijnendijk and Forrest highlight the association between nineteenth-century urban parks and human health described in the previous section, and they note a few instances where human health was invoked to support tree planting; but this relationship does not surface as an important rationale.<sup>64</sup>

Indeed, the aforementioned histories of urban trees do not identify human health as an underlying driver; instead, the aesthetic, democratic, and urban design function of trees emerge as principle considerations. Other narratives related to urban park and greening history do draw associations between trees and human health. Predicated on air quality improvement via miasma theory, Szczygiel and Hewitt point to the writings of Olmsted and Chicago physician John Henry Rauch, who argued that “tree planting would not only break the force of the wind [which spreads miasma], supply warmth in winter, and coolness in summer and thus moderate the extremes of temperature [which influence miasmatic releases and morbidity rates], but at the same time absorb to a considerable extent the noxious gases which are generated in every populous city—supplying oxygen, and thus contributing to the public health.”<sup>65</sup> By screening views to buildings, trees were also important elements of nineteenth-century urban parks intended to help visitors achieve greater psychological distance from everyday cares, in line with English landscape and moral therapy.<sup>66</sup>

## Human Health Benefits of Urban Greenery

The past two decades have witnessed a raft of new research on the health benefits of nature contact. A search in the Web of Knowledge for just one term, “greenspace and health,” yielded two hits for 1990–1999, 34 for 2000–2009, and 45 from 2010 to June 2013.<sup>67</sup> Urban parks were the most commonly studied type of setting. The scientific literature on this topic is in fact much larger than that search revealed, as there are many terms currently in use that are synonymous with green space. Other recent reviews include a perspective essay offering a theoretical framework toward better understanding of the relationship between green space and health;<sup>68</sup> a mini review suggesting that enhanced immune function may be a central pathway linking nature contact and health;<sup>69</sup> a primer seeking to bridge literature on green infrastructure, ecosystem services, and human health;<sup>70</sup> and a systematic assessment of peer-reviewed studies examining the relationship between quantity and quality of green spaces in the living environment and three health outcomes: perceived general health, perceived mental health, and (all-cause) mortality.<sup>71</sup>

While some research points to mixed or weak associations,<sup>72</sup> many studies now show beneficial links between green space and a range of human health outcomes including, but not limited to: self-reported physical and mental health,<sup>73</sup> perceived general health,<sup>74</sup> health-related quality of life,<sup>75</sup> clusters of physician assessed morbidity,<sup>76</sup> risk of stroke mortality,<sup>77</sup> human immune function,<sup>78</sup> mental distress and life satisfaction,<sup>79</sup> risk of small-for-gestational-age births,<sup>80</sup> birth weight in a lowest socioeconomic group,<sup>81</sup> type 2 diabetes mellitus,<sup>82</sup> levels of income-related health inequality,<sup>83</sup> and survival of senior citizens.<sup>84</sup> The first systematic review of epidemiological studies examining relationships between green spaces in the living environment and health showed strong evidence for significant positive associations between the quantity of green space (objectively measured around the residence) and perceived mental health and all-cause mortality, and moderate evidence for an association with perceived general health.<sup>85</sup>

This suggests that people can and do derive human health benefits from contact with nature.<sup>86</sup> The etiology (causal pathway) underlying this relationship, however, is unclear. Kuo has suggested twenty-one possible pathways,<sup>87</sup> while Lachowycs and Jones have identified three potential mediators: perceptions of the living environment; aesthetic pleasure and relaxation from viewing green space; and use of green space.<sup>88</sup> Yet most studies—including a systematic assessment and review of fifty-nine reviews by Hartig et al.—identify four pathways: air quality, physical activity, social cohesion, and stress reduction.<sup>89</sup> The ensuing section briefly summarizes current findings on these topics.

### Air Quality

As noted previously, vegetation in cities has a long-standing association with air quality improvement. Contemporary research on this subject can be organized in two overarching lines of inquiry: one emerging from natural science and the other from public health. The first of these explores three principle mechanisms: deposition of fossil-fuel air pollution onto leaf surfaces and branches, dispersion of fossil-fuel air pollution through the effect of

urban flora upon air circulation, and emission or mitigation of volatile organic compounds (VOCs). Other potential mechanisms include reduction of air pollution emissions from power plants via microclimatic cooling/wind-sheltering effects of trees near buildings<sup>90</sup> and reduced formation of ground-level ozone ( $O_3$ ) through ambient and surface cooling.<sup>91</sup> From a public health standpoint, however, these are fairly distal pathways and they are not included here.

Petroff et al. reviewed literature on deposition and found that different modeling approaches yield large differences in predicted reduction of particulate matter (PM); model results are often not validated with empirical measurements; and detailed quantification of canopy characteristics such as leaf size, shape, orientation, and porosity in addition to leaf area index (LAI) is required to make reliable predictions of deposition filtration effects.<sup>92</sup> Litschke and Kuttler found that the average published value for deposition corresponds to a  $\sim 1$  percent reduction of  $PM_{10}$  in urban areas; large expanses of vegetation (in excess of 10,000  $m^2$  or 2.5 acres) would be needed to mitigate local vehicle emissions; and conifers are more effective filters than broad leaved species. They also note that some in-situ measurements indicate deposition velocities considerably higher than the average published value, and if these results were confirmed by further measurements, local planting campaigns covering small areas could reduce particle concentrations.<sup>93</sup> Reviewing literature on deposition and dispersion, Janhäll focused less on critical assessment of methods and magnitude of potential benefits, and instead offered speculative design recommendations. The paper concludes that both deposition and dispersion—in addition to plant characteristics such as hairiness, stickiness, LAI, and porosity—need to be well understood before greening is systematically incorporated into urban planning as a strategy to improve air quality.<sup>94</sup> This is partially predicated upon studies showing that streetside vegetation, where people often walk and bike, may concentrate air pollution by reducing air circulation.<sup>95</sup>

Some deposition modeling studies of air pollution mitigation by urban trees have extended findings to estimates of human health outcomes. Nowak et al. assert that  $PM_{2.5}$  reduction from tree canopy in ten U.S. municipalities saves on average one life per year per city;<sup>96</sup> and the removal of fossil fuel air pollution by urban trees across the conterminous United States may lead to 850 fewer deaths and 670,000 fewer incidences of acute respiratory symptoms.<sup>97</sup> However, the assumptions, methods, and communication of findings from these modeling studies have been the subject of critique.<sup>98</sup>

A third mechanism by which urban vegetation may affect urban air quality regards volatile organic compounds (VOCs). Virtually all plants emit VOCs as a form of communication between plants, and between plants and insects during plant reproduction, growth, and defense.<sup>99</sup> These emissions are relatively harmless if released in remote areas, but in urban areas they can create ground-level ozone ( $O_3$ ) and PM through interactions with anthropogenic VOCs and nitrogen oxides (NOx) in the presence of sunlight.<sup>100</sup> Churkina et al. compiled several studies confirming a strong influence of biogenic VOC emissions upon diminished urban air quality in Asia, Europe, and North America.<sup>101</sup> However, tree canopies can also remove  $O_3$  through stomatal and nonstomatal processes.<sup>102</sup> One review

concluded that realistic estimations of losses and gains of O<sub>3</sub> due to urban vegetation are challenging, and highly dependent upon local climate conditions.<sup>103</sup>

The aforementioned research has focused on air quality as an ecosystem *function*—the intermediate processes, flows, or conditions that may directly or indirectly generate benefits to humans.<sup>104</sup> These benefits are commonly referred to as ecosystem *services*, and human health has been identified as the central aspect of these services.<sup>105</sup> The distinction between ecosystem functions and services is, however, often unclear in scholarly and popular discourse.<sup>106</sup> Moreover, ecosystem services research tends to focus on ecosystem functions, and rarely assesses actual human health outcomes. For example, a 2013 review of 463 studies addressing urban ecosystem services found that eighteen journals have published at least five or more papers; but none of these journals was from epidemiology. And when characterizing this body of research in five categories, none explicitly addressed public health.<sup>107</sup>

This is a noteworthy gap.<sup>108</sup> In the case at hand, epidemiological scholarship tells a different story from ecosystem services literature regarding links between urban trees, air quality, and respiratory health. Public health research shows consistent associations between urban flora, pollen allergenicity, and asthma-related outcomes including: seasonal peaks in adult and pediatric emergency department (ED) visits,<sup>109</sup> hospitalization,<sup>110</sup> allergic sensitization among children,<sup>111</sup> and both over-the-counter purchases and prescriptions of allergy medications.<sup>112</sup>

Further complicating the picture, tree pollen may interact with air pollutants to exacerbate the development of allergic sensitization. Laboratory studies have repeatedly found that mice exposed to both pollen and diesel exhaust particles are more likely to become sensitized to pollen than mice exposed to pollen alone,<sup>113</sup> while results from epidemiologic research have been less consistent.<sup>114</sup> Of note, a recent study assessing how air pollutants (NO<sub>x</sub>, PM<sub>2.5</sub>), humidity, and tree pollen together influence asthma ED visits found that the highest quartile of daily tree pollen counts resulted in consistently high asthma ED visits, regardless of pollutant or humidity measurements. By contrast, on days when humidity and air pollution levels were high but tree pollen counts were low, asthma ED visits were not significantly increased.<sup>115</sup> This suggests that in some locales, tree pollen may be the major contributor toward increased asthma morbidity.

In sum, public health research on urban vegetation and asthma suggests that the principle outcome may be that of an ecosystem *disservice*, an ecosystem function that negatively affects human health and well-being.<sup>116</sup> Other studies addressing links between trees and air-quality-related health outcomes show mixed results. A natural experiment found increased human mortality related to cardiovascular and lower-respiratory-tract disease following the loss of 100 million ash trees (*Fraxinus* spp.) due to an invasive beetle infestation. However, this study did not identify air quality improvement as an etiological pathway. It also spanned 1,296 counties across 15 midwestern U.S. states, and did not address the effect of *urban* trees per se. This is an important consideration, as the ecosystem function of trees in cities may be quite different from nonurban trees.<sup>117</sup> Focusing

more directly on urban areas, Pilat et al. found no significant correlation between canopy cover and childhood asthma in 25 metropolitan statistical areas in Texas.<sup>118</sup>

Current literature raises fundamental questions about the long-standing belief—popularized in the nineteenth century through association with miasma theory—that urban flora improves air quality in cities. Importantly, green space is not a substitute for reducing pollution at its source, and while urban vegetation may have some capacity to filter pollutants from the air, it is nowhere near the levels that would counteract the magnitude of emissions.<sup>119</sup> Moreover, there is a threshold at which air pollution can harm the very vegetation that may filter these pollutants and provide other important benefits.<sup>120</sup>

### Physical Activity

The world is experiencing a pandemic of physical inactivity and obesity.<sup>121</sup> While the etiology of obesity is complex,<sup>122</sup> excess energy consumption (dietary intake) relative to energy loss via metabolic and physical activity may be the most common cause.<sup>123</sup> Increasing total physical activity is thus an important strategy to address obesity, as well as overall physical and mental health across the life span.<sup>124</sup> Total physical activity can be characterized in three domains: work (e.g. construction; house cleaning); active transport (e.g. biking/walking to a destination); and leisure/recreation (e.g. jogging for exercise). Of these domains, the latter two are the most relevant for assessing links with urban greenery.

Active transport (biking/walking) may be increased through natural features and vegetation by making routes more attractive. Yet Hartig et al. marshal evidence that distance to destination, availability of suitable infrastructure (e.g. sidewalks, bike paths), and safety are more important factors. They also cite two systematic reviews showing mixed findings, as well as studies suggesting that the same holds true for children and the elderly.<sup>125</sup> Provision and access to green space and parks may in turn increase both leisure and active transport. However, reviews and studies addressing these associations also show mixed findings.<sup>126</sup>

Given the important role that physical activity is assumed to play in health-based arguments for green space, it is surprising that few studies have investigated the extent to which physical activity levels might mediate associations between nature and human health outcomes. Of four studies addressing this relationship, Hartig et al. only found one concluding that physical activity (recreational walking) was an important mediator.<sup>127</sup> The green space/physical activity relationship is further problematized when considering the broader literature on built environment correlates of physical activity and obesity. Here, several review studies reveal complex patterns and inconsistent associations.<sup>128</sup> Baumen et al. conclude that few environmental correlates have been identified for either transport or recreation activity,<sup>129</sup> and several studies on leisure activity suggest that individual and social factors may be of equal or greater importance than the built environment.<sup>130</sup>

This may not, however, discount a relationship between green space and obesity. Kuo cites ten studies tying greener residential areas with lower rates of obesity, and suggests that this may depend less on links to physical activity and more on associations between

nature contact and stress, impulse control, and adiponectin (a protein involved in regulating glucose levels and fatty acid breakdown).<sup>131</sup> This would seem to be supported by several review studies showing beneficial mental health outcomes from exercising in greener areas.<sup>132</sup> Yet a review of sixty studies found mixed and inconsistent findings on links between green space and obesity.<sup>133</sup> One study also found that residents of sprawling U.S. counties—who ostensibly live amid more greenery—were likely to walk less during leisure time, weigh more, and have greater prevalence of hypertension than residents of compact counties.<sup>134</sup> This points to the need for greater clarity regarding land use and urban form in the human health and nature contact literature.

### Social Cohesion

Defined as the norms of reciprocity and trustworthiness that arise from social networks, social cohesion (or connectedness) is a powerful determinant of human health.<sup>135</sup> Unlike physical activity, the environmental correlates of social cohesion have not been the subject of extensive research, but existing studies generally suggest a positive relationship.<sup>136</sup> This scholarship can be broadly organized by outcomes related to antisocial behavior and prosocial behavior.<sup>137</sup> To the best of this author's knowledge, a clear distinction between antisocial and prosocial outcomes has not been made in the nature contact literature.

Studies addressing links between green space and antisocial outcomes focus largely on crime-related activity, fear, and interpersonal aggression. Early studies showed that people associate dense, unmaintained vegetation with feelings of reduced security,<sup>138</sup> and fear of crime,<sup>139</sup> by blocking views and providing a hiding place for criminals.<sup>140</sup> This supported urban crime control strategies to remove vegetation.<sup>141</sup> Subsequent research suggests that well-maintained greenery can have an opposite influence by deterring criminal activity through three potential mechanisms: (1) signaling social ties and order, consistent with “broken windows” and “incivilities” theories;<sup>142</sup> (2) increasing informal surveillance through more use of public space and increased “eyes on the street”<sup>143</sup> which is a component of “routine activity” theory in criminology;<sup>144</sup> and (3) mitigating mental fatigue.<sup>145</sup>

Pioneering site-scale studies in Chicago public housing developments showed systematically more violent crimes at buildings with the least vegetation,<sup>146</sup> and higher levels of household aggression and violence among residents in buildings with views onto concrete and asphalt than counterparts living in identical buildings with views of trees.<sup>147</sup> Cleaning and greening over 4,400 vacant lots in Philadelphia has, in turn, been associated with consistent reductions in gun assaults.<sup>148</sup> And a follow-up study—the first randomised controlled trial of vacant lot greening—found preliminary evidence for reduced violent crime and increased perceptions of safety.<sup>149</sup> At a lower density, small, view-obstructing lot trees at 2,813 single-family detached homes were associated with increased crime occurrence, whereas large lot trees and street trees in the public right-of-way tended to suppress crime.<sup>150</sup> Exploring citywide effects, researchers found that vegetation abundance in Philadelphia was significantly associated with lower rates of assault, robbery, and burglary, but not theft.<sup>151</sup> Expanding to an urban-rural metropolitan gradient, others showed a 10 percent increase in tree canopy associated with a roughly 12 percent decrease in crime. Here,

trees on public land had a greater negative association with crime than private land trees.<sup>152</sup>

Shifting to prosocial outcomes, early studies focused on low-rise and high-rise low-income residential settings in Chicago. Here, the presence and proximity of trees and grass attracted both larger groups and encouraged greater mixing of adults and youths compared to areas without vegetation.<sup>153</sup> Individuals living next to greener common spaces had more neighborhood social ties (NSTs), characterized by more social activities and visitors, knowing more neighbors, more concern with helping and supporting one another, and stronger feelings of belonging. Studies with statistical tests of mediating processes indicated that greater use of green spaces explained the link to NSTs,<sup>154</sup> which have been linked to lower risk of stroke,<sup>155</sup> chronic health impairments, and emotional distress.<sup>156</sup> Interviews with the elderly also showed that use of green outdoor common spaces predicted both NSTs and strength of sense of community.<sup>157</sup>

Questions remain as to whether the aforementioned social cohesion outcomes associated with urban green space mediate an eventual relationship with human health. Hartig et al. identified no studies on mediation by antisocial outcomes related to aggressive behavior, fear of crime, and/or crime rates. They did, however, identify four studies addressing the mediation effect of prosocial outcomes of nearby nature. One cross-sectional study found that feelings of loneliness and perceived shortage of social support partially mediated the relationship between green space within one kilometer and overall health, and fully mediated neighborhood greenness and psychiatric morbidity.<sup>158</sup> Another study showed that perceived social quality and social well-being mediated relationships between quantity and quality of streetscape vegetation and both overall and mental health.<sup>159</sup> A third found that social coherence partially mediated the link between perceived neighborhood greenness and mental health.<sup>160</sup> However, Francis et al. found neither social support nor sense of community to be a meaningful mediator linking the quality of public open space and mental health.<sup>161</sup>

A topic that the green space/social cohesion literature has not sufficiently grappled with is the association between parks and race relations. One study found that urban parks can serve as “boundary landscapes” that separate neighborhoods of distinct socioeconomic characteristics.<sup>162</sup> Others report that parks can abet racial discrimination,<sup>163</sup> while some suggest that urban parks promote positive interaction between different ethnic groups.<sup>164</sup>

Contemporary literature on links between nature contact and social cohesion offers tentative support for nineteenth-century thinking related to urban green space as important elements supporting a pluralistic and civil society. Research showing reduced aggression amongst residents with more views onto trees and lawn, and more prosocial behavior in greener common spaces, resonates with depiction of the Olmstedian landscape: “the restorative purposes of the park were accomplished both through a noncompetitive, non-threatening “coming together” and through the restful contemplation of natural scenery.”<sup>165</sup> And while nineteenth-century street tree planting may not have intended to



Figure 3. Before (inset, 2000) and after (2012) image of vacant lot greening at the corner of 5th Street and Berks Street in Philadelphia, Pennsylvania. (Pennsylvania Horticultural Society, LandCare Program)

reduce crime, the desire to improve the public realm is supported by contemporary literature linking reduced crime with street trees and vacant lot cleaning/greening. A noteworthy consideration is that this relationship may be due, in part, to the way these greening interventions communicate cues to care and promote eyes on the street, rather than contact with vegetation per se (see Figs. 2 and 3).

#### Stress Reduction

Defined as the psychophysiological phenomenon caused when environmental demands reach or exceed an organism's capacity to address those demands,<sup>166</sup> stress is associated with overall human health.<sup>167</sup> Since the early 1980s, a raft of true and quasi-experimental studies conducted in laboratory and field settings have assessed a range of affective (emotional), cognitive, and physiological outcomes related to more or less exposure to naturalistic settings. Most of this research has been conducted in the urban context.<sup>168</sup> In 2004, a review by the Health Council of the Netherlands judged the evidence for the restorative influence of nature contact to be strong.<sup>169</sup> This is supported by a 2010 review by de Vries,<sup>170</sup> a 2015 review by Kuo,<sup>171</sup> and a 2014 assessment of 59 reviews by Hartig et al., which concludes that substantial evidence speaks to the potential benefits of nature contact for avoiding health problems traceable to chronic stress and attentional fatigue.<sup>172</sup>

In cities, benefits are likely derived in two ways. First, by providing a visual and auditory barrier to challenging environmental conditions, green spaces may diminish people's apprehension of potential stressors. Second, green space can help people to restore adaptive resources. This restorative quality does not merely depend on the absence of stressors, which can motivate people to escape the social and environmental pressure of cities through recreation in more natural settings. It can also be defined in positive terms, wherein nature contact yields beneficial outcomes in and of itself.<sup>173</sup>

Two principal theories may explain how restoration can occur once a person has achieved perceptual distance from stress-inducing influences. *Psycho-evolutionary theory*,<sup>174</sup> also described as *stress reduction theory* (SRT),<sup>175</sup> suggests that as a partly genetic remnant of evolution, modern humans have a biologically prepared capacity for acquiring and retaining restorative responses to certain nature settings and content (e.g., vegetation, flowers, water), but have no such disposition for most built environments and their materials. These evolutionary arguments suggest that nature settings may be especially effective in promoting restoration if they possess verdant plants, calm or slowly moving water, some spatial openness, park-like or savanna-like properties (e.g., scattered trees, grassy understory), unthreatening wildlife (e.g., birds), and a sense of security or low risk.<sup>176</sup> *Attention restoration theory* (ART), on the other hand, holds that people process information either through directed attention or fascination. Directed attention sorts information we use to solve daily problems and it is a highly limited resource that can be exhausted—especially in urban settings—without opportunities for recovery. People recover best in environments such as nature settings more consistent with our collective past.<sup>177</sup>

These theories share a supposition that people benefit from encountering environments to which they are innately adapted, but they differ in ART's focus on cognitive processing and SRT's focus on autonomic processing.<sup>178</sup> It is interesting to note that ART aligns with the mid-nineteenth-century writing of Olmsted: “[natural scenery] employs the mind without fatigue and yet exercises it; tranquilizes it and yet enlivens it; and thus, through the influence of the mind over the body, gives the effect of refreshing rest and reinvigoration to the whole system.”<sup>179</sup> Yet the built expression of this thinking reflects characteristics associated with psycho-evolutionary theory, namely, a savanna-like setting that may be perceived as favorable because it offered early humans high potential for securing food and water (see Fig. 4).<sup>180</sup> In either case, a century and a half later, contemporary science largely supports the intuition of Olmsted regarding the restorative influence of contact with nature.<sup>181</sup>

One of the challenges and potential weaknesses of research linking stress reduction with nature contact is heterogeneity of methods. A review by Bowler et al. pooled the effect size of four to eight studies of the most commonly measured outcomes, and found improvements in mental health outcomes related to stress such as feelings of anger, anxiety, energy, fatigue, and sadness.<sup>182</sup> Stress may also be a factor in other health outcomes associated with green spaces. As noted earlier, links between obesity and green space may be less related to physical activity than to stress, impulse control, and adiponectin.<sup>183</sup> Stress is also a risk factor for asthma,<sup>184</sup> and it is not unthinkable that urban greening—



Figure 4. Comparison of a savanna landscape with the naturalistic landscape architecture of Frederick Law Olmsted, Sr. Image on left: Serengeti National Park in Tanzania, 2012. (Courtesy of Michal Bednarek) Image on right: Prospect Park in Brooklyn, New York, 2010. (Matthew X. Kiernan/New York Big Apple Images)

especially with low pollen-producing species—could potentially reduce this disease through stress reduction.

### Contemporary Greening and Human Health

We are now living during a noteworthy inflection point in cultural and natural history. As recently as the early eighteenth century, the natural world for preindustrial New Yorkers existed, “not in pictures or in books, but was the fabric of their everyday lives.”<sup>185</sup> Yet by the end of this century, some three-quarters of all human beings will be living in cities,<sup>186</sup> and the average American already spends over 90 percent of his or her life within buildings.<sup>187</sup> The rapid transition to urban and indoor environments over roughly the past two centuries—a mere seven to ten generations—coincides with disconnection from natural landscapes and a dramatic break from the *longue durée* of human evolution.<sup>188</sup> Indeed, “humanity has not been down this road before; there are no precedents, no guideposts.”<sup>189</sup>

Intuition alone suggests that a species that is transitioning to a fundamentally different habitat would benefit from connection to the landscape elements from which it evolved over millennia, and there is evidence that people living in cities derive greater health benefits from nature contact than those living in less urban areas.<sup>190</sup> Of the four pathways described in this review, stress and related psychological outcomes emerge as, perhaps, the most reliable health benefit of green space. Well-maintained vegetation in the public realm and in shared spaces may also improve health by facilitating social cohesion, a topic of interest in an urbanizing world.<sup>191</sup>

The psychosocial benefit of municipal greening is noteworthy, as urban living has been linked with more mental illness,<sup>192</sup> mental disease,<sup>193</sup> and greater difficulty coping with stress.<sup>194</sup> These disamenities do not, however, undermine the advantages associated with urbanism such as higher levels of literacy and education, better overall health, greater access to social services, and enhanced opportunities for cultural and political participation.<sup>195</sup> Of note, Olmsted was a strong proponent of urbanization and he saw the greening

of cities through parks as an important strategy to ameliorate the psychosocial disadvantages of what was otherwise one of the most liberating forces in human history.<sup>196</sup>

Yet the pastoral schemes of the nineteenth-century park may not necessarily be an appropriate norm for twenty-first-century urban greening, especially in largely built-out postindustrial cities.<sup>197</sup> Today, a new generation of urban greening innovation is being implemented, and it may have a similar transformative effect upon urban form and the lived experience of cities as street trees and parks did in the nineteenth century. This includes but is not limited to large-scale tree planting;<sup>198</sup> Green Area Factors;<sup>199</sup> green roofs and walls;<sup>200</sup> green infrastructure for stormwater management;<sup>201</sup> railways, highways, and landfills retrofitted to green space;<sup>202</sup> vegetated bridges, walkways, traffic islands, lamp posts, overhead wires, balconies, and window boxes;<sup>203</sup> vacant lot greening;<sup>204</sup> and community gardens.<sup>205</sup>

These contemporary forms of greening are often implemented at the site or block scale, taking advantage of underused surfaces in the urban fabric. Serendipitously, these relatively small, distributed interventions are often in close proximity to people's daily lives and may have the capacity to provide health benefits through regular contact with green spaces. This touches on the issue of dosage—the frequency, duration, and type of nature contact—which is an open question and needs to be handled with care.<sup>206</sup> For example, discrete encounters with green space to which one must travel may not have a long-lasting health effect.<sup>207</sup>

This is supported by a set of studies in Chicago, where Kuo and Sullivan concluded that, “a few major parks are not enough.”<sup>208</sup> Trees and grass in small areas outside public housing apartment buildings had a clear association with residents' levels of aggression, NSTs, and coping with stressful life issues. Importantly, all residents here lived within 2 miles (3.2 km) of parks along Lake Michigan, but those large natural areas were insufficient to keep all residents at similar levels of attentional functioning. Indeed, several studies suggest that regular exposure to nearby flora may be especially important in urban settings.

A review of links between urban design and human health found that “at the parcel scale, greenery and access to it visually and physically are the principal keys to health.”<sup>209</sup> Streetscape vegetation was at least as strongly related to self-reported health as green areas in the Netherlands,<sup>210</sup> and the strongest links between greenness and reduced morbidity were found closest to home: within 1 km (0.6 mile) or roughly a 10-minute walk.<sup>211</sup> In Seattle, physical proximity to nature areas did not have a strong effect on neighborhood satisfaction, whereas visual proximity to vegetation did.<sup>212</sup> Another study found that greenness of the living room view fully mediated the relationship between greenness and neighborhood satisfaction,<sup>213</sup> suggesting the need for green space to be “evaluated in terms of visual proximity, that is, whether and how it is experienced from the street and the home.”<sup>214</sup> Indeed, more street trees has been linked with fewer antidepressant prescriptions,<sup>215</sup> and being in view of a greened vacant lot decreased heart rate significantly more than being in view of a non-greened vacant lot or not in view of any vacant lot.<sup>216</sup> This is supported by research on window views,<sup>217</sup> including Ulrich's classic finding that hospital



Figure 5. Streetscape in Seattle, Washington, that meets the Green Factor requirement for commercial zones, 2012. (City of Seattle Office of Planning and Community Development)

patients with windows looking out on a small stand of deciduous trees had significantly shorter postoperative hospital stays, received fewer negative evaluative comments in nurses' notes, and took less pain relief medication than matched patients in similar rooms with windows facing a brick building wall.<sup>218</sup>

Combined with the types of urban greening that are already being implemented today, this points to *proximal greening* as a distinct form, and possible norm, for twenty-first-century urban design (see Fig. 5). This supports Kaplan's call for "nature at the doorstep" three decades ago,<sup>219</sup> predicated on repeated, short-term exposures to greenery that may provide cumulative benefits through "micro-restorative opportunities."<sup>220</sup> Proximal greening does not, however, discount the need for a larger interconnected network of city, metropolitan, and regional green spaces.<sup>221</sup> Due to their elongated geometry and large perimeter-to-area ratio, linear parks and greenways may be an especially important strategy to increase access to green space.<sup>222</sup>

In addition to providing wildlife habitat and ecosystem functions, there is also strong evidence for a positive association between the quantity of green space in people's living environment and perceived mental health and mortality due to all causes in general adult populations.<sup>223</sup> This may be especially important in the fast-urbanizing regions of Africa and Asia, where cities will in all likelihood need to expand their physical footprint in order to accommodate millions of new residents.<sup>224</sup> Green space conservation may also be an important preemptive strategy in planning for the growth of informal settlements,<sup>225</sup>

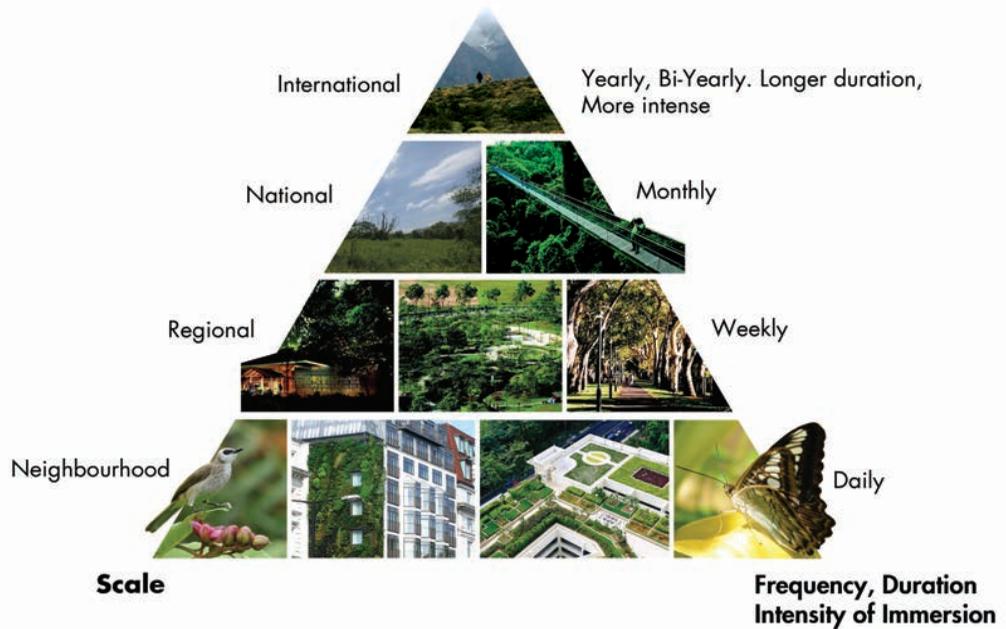


Figure 6. Conceptual diagram of the Nature Pyramid, 2012. (Concept by Tanya Denckla-Cobb and Timothy Beatley, University of Virginia, Department of Urban and Environmental Planning. Illustration prepared by Singapore National Parks Board.)

especially as people with lower socioeconomic status seem to benefit more from green spaces in the living environment than people with high socioeconomic status.<sup>226</sup>

Reflecting a hierarchy of nature contact scale and exposure, Beatley and Denckla-Cobb have proposed a four-tiered Nature Pyramid, wherein neighborhood greenery provides “the bulk of our nature diet” (see Fig. 6).<sup>227</sup> This provides a potentially compelling framework to bridge urban greening practice with scholarly research, which has identified a need to better link health outcomes more directly to *types* of green spaces,<sup>228</sup> while accounting for both *quantity* and *quality* of green spaces.<sup>229</sup> In light of the rapid urban greening innovation occurring today, practice-based research may be especially important.<sup>230</sup>

In sum, the urbanizing eras of the nineteenth and early twenty-first centuries show a corollary interest in urban greening, partially predicated on a recurring theme that human health is an important benefit of such activity. While the practical outcomes and scholarly insights on this topic may change over time, urban greening reflects an enduring aspiration to merge city with nature. Environmental determinants are just one among many other sociopolitical factors that are essential to human health and well-being.<sup>231</sup> But if one subscribes to at least a partial belief that “we create the city, then it creates us,”<sup>232</sup> then the effect of urban greening upon human health will be an important topic of research and practice in the forthcoming century of the city.

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