Toward Improved Public Health Outcomes From Urban Nature

There is mounting concern for the health of urban populations as cities expand at an unprecedented rate. Urban green spaces provide settings for a remarkable range of physical and mental health benefits, and pioneering health policy is recognizing nature as a cost-effective tool for planning healthy cities.

Despite this, limited information on how specific elements of nature deliver health outcomes restricts its use for enhancing population health. We articulate a framework for identifying direct and indirect causal pathways through which nature delivers health benefits, and highlight current evidence.

We see a need for a bold new research agenda founded on testing causality that transcends disciplinary boundaries between ecology and health. This will lead to cost-effective and tailored solutions that could enhance population health and reduce health inequalities. (*Am J Public Health.* 2015; 105:470–477. doi:10.2105/AJPH.2014.302324)

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MORE THAN 70% OF THE world's population will live in cities within 30 years,[1,2] igniting concern about the health challenges resulting from urbanization.[3] Effective planning of the physical fabric of our future cities is foundational for delivering enhanced and equitable health outcomes,[4] and powerful new evidence highlights the critical role that urban nature and green infrastructure can play in shaping healthy cities. However, knowledge of how natural environments benefit health remains rudimentary at best, and almost all evidence so far is correlative.[5,6] If real progress is to be made in designing health-promoting green infrastructure, ecologists and health scientists must begin working closely together to tease apart the causal mechanisms involved.[7,8]

Here we outline a framework for examining causality, and identify some plausible pathways connecting the natural environment with health outcomes. We conclude that there is a need to shift attention to how, not whether, nature influences health. This new research direction will provide the foundation for strategies that will shape urban nature to deliver better health outcomes for communities, and ultimately could assist in reducing health inequalities.

URBAN NATURE AND HEALTH POLICY

Pioneering health policies have begun to recognize nature as a means to enhance population health in cities, including initiatives from the United Kingdom,[9] Scotland,[10] United States,[11] and Australia.[12] This reflects a fundamental shift in public health discourse from a focus on risk factors, such as insect-borne diseases and pollen as an allergen, to a broader view that also encompasses the potential benefits of nature.[13,14] These benefits span a remarkable breadth of health outcomes, with correlational evidence for reduced all-cause mortality and mortality from cardiovascular disease,[15,16] improved healing times[17] and self-perceived general health,[18] reduced stress,[19] reduced respiratory illness and allergies,[20,21] improved self-reported well-being and a reduced risk of poor mental health,[22–24] improved social cohesion,[25] and improved cognitive ability.[26,27]

However, a rudimentary knowledge of the underlying causal pathways means that policy frameworks often lack key ecological insights into the design of urban green spaces, employing primarily broad provision-based targets such as proximity to residential areas and minimum sizes of parks.[28] For example, accessible natural green space standards for the United Kingdom specify area-based targets for green space that should be made available within certain distances of people's homes,[29] and the United Nations Habitat State of the World's Cities report cites the need for green space provision of at least 8 square meters per capita.[30] Other nature-based planning objectives that could enhance health fall under the umbrella of environmental protection or sustainability policy.[31,32] Delivering on these green space and environmental protection objectives will provide urban residents with some opportunity to gain health benefits from nature,[33] but this approach falls well short of optimal planning of green infrastructure for cost-effective and targeted health outcomes. Guidelines are urgently required to assist policymakers in identifying nature-based interventions that can be tailored to meet the health needs of diverse urban communities.

Allied to the lack of information on causality is an absence of clear evidence about which elements of nature deliver which health outcomes. This stems in part from the fact that even the most powerful studies have used a broad definition of nature itself. For example, influential research lead by health scientists used extensive long-term data sets from the United Kingdom to reveal a correlation between exposure to nature and general health and life satisfaction,[34] as well as all-cause mortality and mortality from cardiovascular disease.[15] The measure of nature used in these studies was the area of public green space in a neighborhood. Although such land cover metrics are useful for urban planning, they cannot provide information on which ecological properties (i.e., measurable elements of nature) might be driving the health effects, or how specific ecological properties might be manipulated to enhance the outcomes. Do similar health benefits flow from a park comprising a closely mown lawn and one that is much more biologically diverse?

The few studies that have examined the correlation between health and well-defined ecological properties have found conflicting results. For example, 3 separate studies led by ecologists reported different effects of the number of bird and plant species in an area (species richness) on self-reported well-being; they variously found a positive effect,[23] an effect that was dependent on perceived species richness,[22] and no effect.[35] Such variation can arise for a number of reasons, including physical and social differences between participants, and differences in well-being measures.[20] Nonetheless, such studies suggest that variation in nature itself, not just the general levels of provision of green space, has an important role in enhancing population health.

Closer examination of variation in nature may also help explain apparently contrasting evidence of the link between nature and health; for example, tree cover has been found to have both positive[20] and negative[36] relationships with respiratory illness, asthma, or allergies in population-level studies. These varying results may be in part explained by ecological properties such as the life-history traits of the tree species present, including differences in pollination strategies (e.g., wind or insect) and duration of pollination.[37] We see these relationships as an opportunity for truly interdisciplinary research that brings ecologists and health scientists together to understand the mechanisms behind how nature benefits human health.

PATHWAYS TO HEALTH BENEFITS

Unpacking cause and effect in the relationship between nature and health is a complex task; the links can be both direct and indirect, displaced in space and time, and influenced by a range of moderating forces.[7,8,38] Direct pathways are the most straightforward, and include instances in which specific elements of nature function in a way that influences the physical characteristics of the environment, thereby reducing risk factors to human health. An example of this is where tree cover directly improves air quality by filtering particulate matter[39] (see the box on this page). This biological function of the trees could reduce the incidence of respiratory illness,[20,39] and the causal pathway is not difficult to envision. There may be only a few moderating factors involved in direct pathways; that is, factors that influence whether nature has an effect on people or the extent to

Examples of Pathways to Health Benefits From Nature

Example 1: A Direct Pathway to Physical Health Benefits

Measurable ecological properties of vegetation in urban environments include the proportion of a specified area that is covered by trees, shrubs, and herbaceous plants at different heights, as well as the total biomass of that vegetation (step 1). These elements of nature ameliorate the urban heat island effect[40,41] by providing shade, a surface that reflects heat away from the ground, and through evapotranspiration (where water evaporates into the atmosphere from leaf surfaces allowing the transfer of heat energy away from the ground[39,41]; step 2). This change is likely to have the greatest effect on people who live or work in the vicinity of the vegetated areas (step 3), as it can result in improved temperature regulation and reduced summertime temperatures in hot climates (temperature reductions of 5˚C to 20˚C are possible[40,42]; step 4). A health benefit may result where high temperatures are a public health issue, or where a significant proportion of the population is susceptible to heat stress (e.g., a high proportion of elderly residents[40]; step 5). The presence of vegetation locally (e.g., around buildings) and its citywide distribution will influence whether the effect is just local or widespread.[43] Temperature moderation can deliver health outcomes by providing a protective factor for heat-related illnesses (step 6). As a consequence, enhancing vegetation cover is now promoted as a key health policy strategy to manage temperature extremes in many cities around the world.[42,44]

Example 2: An Indirect Pathway to Physical Health Benefits

Ecosystem properties of trees, including leaf area and shape, and the height of tree canopy cover (step 1), contribute to the local climate of an area by regulating temperature and providing shade[40,41,45] (step 2). Ecological properties such as the proportion of an area covered by grass (step 1) can also fundamentally change the physical characteristics of an area by providing a softer ground surface than concrete[39] (step 2). These functions can improve the aesthetics and appeal of a location for physical activity, but this may be influenced by factors such as cultural or social norms related to exercise, personal preferences, and physical ability[46–48] (step 3). This effect could potentially lead to more people meeting daily recommendations for exercise[46,49] (step 4). Depending on moderating factors such as the type of exercise undertaken and individual-level physical factors (step 5), increased physical activity can be a protective factor for heart disease, high blood pressure, obesity, mental illness, and other problems associated with sedentary lifestyles[50–52] (step 6). The role of green space and pleasant scenery in promoting physical activity is becoming increasingly recognized in policy,[53,54] yet there is still minimal knowledge about optimal design of the natural components of urban green spaces for this purpose.

Example 3: An Indirect Pathway to Mental Health Benefits

The number of plant species in an area and the level of herb, shrub, and canopy cover are all measures of vegetation “structural complexity” (step 1). A function of this ecosystem property in urban environments is the provision of a visually complex and diverse environment (step 2). When people view vegetation (step 3), the visual complexity may provide restoration from “directed attention”; that is, where specific focused attention is required for activities[55] (step 4). Cultural or social norms and personal preferences associated with the ecosystem property are also likely to influence the scale or presence of this effect[55] (step 5). Individuals can experience improved mental health through attention restoration in which a person’s mental fatigue is reduced and cognitive function restored[27,55–57] (step 6). The role of natural settings for providing restorative benefits to people has been recognized in some progressive health policy recommendations,[58] though there is still limited knowledge of the specific designs of natural environments that provide the greatest benefits.

Note. These examples utilize the framework presented in Figure 1 for identifying the causal pathways that lead to health benefits from nature.

which that effect translates into a measurable health outcome.

Health policy interventions associated with direct pathways may be relatively straightforward primarily requiring the provision of the natural element where the associated health outcome is desired. For example, vegetation along roadsides is often considered a critical component of urban air pollution policy,[59] and active tree planting initiatives are being implemented in cities including New York, New York,[60] and Sydney, Australia.[61] Spatial planning and careful selection of species for such nature-provision initiatives will enhance the associated health outcomes, as this can help maximize the potential benefits by targeting problem areas and providing the most effective species for the desired effect. This approach will also assist in minimizing the potential negative consequences. For example, while vegetation can filter pollutants from the air, it can also emit potentially harmful aerosols in the form of pollen.[62] Pollen itself can trigger allergies and respiratory illnesses in urban residents.[63] Thus, plant species that rely on the wind for pollen dispersal may not be appropriate for neighborhoods where the incidence of these illnesses is already high.

A more common situation is for nature to provide indirect benefits to human health—for instance, where nature influences the likelihood a person will display positive health behaviors, or where nature reduces the impacts of other risk factors in a person's life (see the box on the previous page). For example, people may be more likely to undertake physical activity where the environment is enhanced by elements of nature.[46,64,65] Designing policy interventions to deliver health benefits via indirect pathways is complicated by a number of moderating factors; personal preference for exercise, social norms associated with exercising, and physical characteristics of individuals could all influence whether physical activity is undertaken outdoors.[46,47] Combined policy initiatives from individual to population-level approaches as well as the provision of appropriate natural environments will often be required.[66]

Some population health outcomes, such as a decrease in the incidence rate of cardiovascular disease in response to increasing vegetation cover, will only be detectable many years after a population is exposed,[15] and movement of people between neighborhoods and even countries can spatially uncouple the cause (varying levels of nature) from the effect (the health outcome). By contrast, other aspects of health, such as improvements in an individual's cognitive function in response to views of nature, can be immediately measurable following exposure,[57] although their long-term relevance to health is not always clear.

Identifying the causal pathways, both direct and indirect, that lead to health outcomes from nature as well as the moderating factors involved are important first steps in pinpointing exactly what types of green infrastructure might deliver specific health outcomes for different communities. In Figure 1 we present a framework that can be used to conceptualize these causal links a priori so they can be robustly investigated, and we describe step-by-step how this framework can be applied with 3 examples described in the box on the previous page.

TOWARD PUBLIC HEALTH OUTCOMES FROM NATURE

We articulate a range of direct and indirect pathways to health

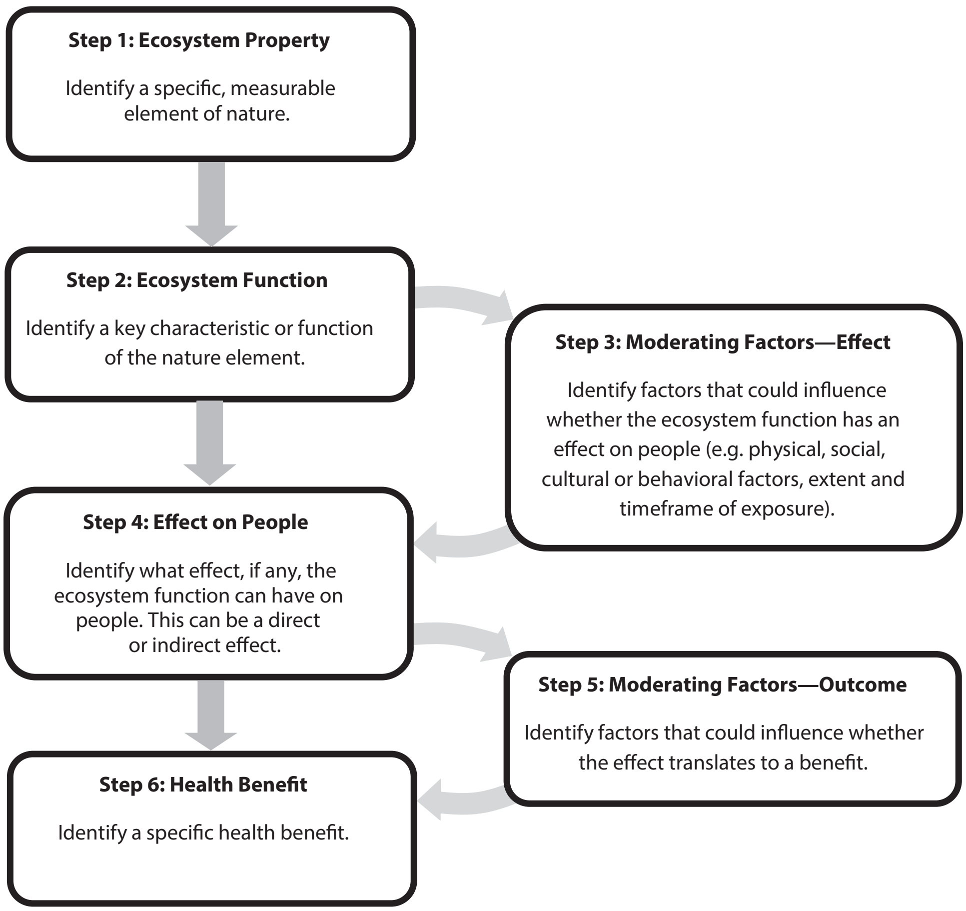

FIGURE 1—A framework for identifying the pathways to health benefits from nature.

TABLE 1—Direct and Indirect Pathways to Health Benefits From Nature

Ecosystem Properties	Ecosystem Functions	Effect on People	Moderating Factors	Potential Health Benefits	References
		Direct pathways to health benefits			
Tree canopy cover; tree canopy height; tree leaf area and shape	Tree canopy shades the ground. The amount of shade provided is influenced by leaf area and shape, and canopy height.	Reduced exposure to UV radiation	Use of shade is required. This may be influenced by individual preferences and knowledge. Health outcomes are influenced by individual-level risk factors, including skin tone, vulnerability to sunburn, and ability to tan.	Shade is a protective factor for skin cancer, sunburn, cataract and other eye diseases.	40, 67, 68
Vegetation biomass; tree cover; leaf area and shape; spatial distribution of vegetation across the landscape and around buildings	Temperature is regulated both in buildings and outside, including reduced hot weather temperatures because of shade provided by trees and high albedo of vegetation cover. Temperatures are increased in cold weather (depending on climate) where vegetation provides a windbreak.	Buffered temperatures experienced	Moderating factors include characteristics of the built environment, such as building design and energy efficiency, and acclimatization of the local population to heat or cold.	Reduced hot weather temperatures are a protective factor for heat related morbidity or mortality. Reduced need for other heating and cooling methods is positive for global environmental health (reduced carbon emissions) and could reduce personal financial burden.	40, 41, 69
Vegetation biomass; leaf area; vegetation structure (including foliage density); type of tree species (deciduous, evergreen); spatial distribution of vegetation	Filtering of air pollutants; foliage density influences effectiveness of filtering as less air flows through dense foliage. Filtering is influenced by deciduousness and the spatial location of vegetation.	Cleaner air inhaled	The scale of effect may be insufficient to cause a change in health outcomes if overall levels of pollution are high.	Cleaner air is a protective factor for respiratory illness and cardiovascular disease.	20, 39, 70
Plant species diversity around living or work environments; number of habitats; number of land-use types	Diversity and abundance of microbiota in soils is maintained or increased.	Increased abundance and diversity of microbiota on the skin and in the gut	Use of outdoor areas may be required. The scale of effect could be influenced at the individual level by factors such as genetic predisposition to allergies, and at what point in life the person was exposed.	Increased immune function could provide a protective factor for allergies, asthma, and other chronic illness associated with altered or reduced microorganisms in the gut or on skin.	21, 71, 72
		Indirect pathways to health benefits			
Grass cover; shrub cover; tree canopy cover; tree canopy height; tree leaf area and shape	Temperature is regulated through shade provision, evapotranspiration, high albedo of vegetation, and wind reduction. The nature present can also assist in the provision of a soft ground surface, and will influence the openness of the space.	Appealing location that encourages physical activity	The appeal of an area will be influenced by individual preferences, cultural and social norms, and local factors such as crime rates. Personal preferences for and ability to carry out physical activity will influence whether people engage with it.	Physical activity provides a protective factor for heart disease, high blood pressure, obesity, mental illness, and other conditions associated with sedentary lifestyles.	33, 45, 73

Continued

TABLE 1—*Continued*

Grass cover; tree cover; shrub cover; presence of water bodies	Temperature is regulated through shade provision, evapotranspiration, high albedo of vegetation, and wind reduction. The nature present can provide a soft ground surface, and will influence the openness of the space.	Appealing location that encourages outdoor and recreational activities (this could include nonphysical activities such as picnicking or bird watching)	The appeal of an area will be influenced by individual preferences, cultural and social norms, and local factors such as crime rates. Personal preferences for outdoor activities will also influence whether a person engages with them.	Sufficient vitamin D, melatonin production, or release of nitric oxide from the skin provides a protective factor for bone diseases, cardiovascular disease, high blood pressure, mental illnesses.	45, 73–75
Grass cover; tree cover; shrub cover; presence of water bodies	Temperature is regulated through shade provision, evapotranspiration, high albedo of vegetation, and wind reduction. The nature present can also provide a soft ground surface, and will influence the openness of the space.	Appealing location that encourages time spent in community space	The appeal of an area will be influenced by individual preferences, cultural and social norms, and local factors such as crime rates. Personal preferences for outdoor activities will also influence whether a person engages with them. The presence of other people may be necessary for enhanced social cohesion.	Social cohesion could be improved through increased contact with members of the local community.	33, 45, 73–77
Structural complexity of vegetation; number of habitats; presence of water bodies	A setting that includes elements of living systems including plants provides a view that requires limited concentration or focus, and does not stimulate a stress response.	Autonomic generation of psychophysiological stress reduction response; recovery from fatigue of directed attention; increase in positive affect	For a benefit to be experienced there must be an interaction between an individual and the nature element. Personal preferences, cultural background, or social norms could influence whether a person finds a particular nature element restorative.	Benefits include improved cognitive function and mental health; potential protective factor for stress related illnesses; possibly reduced blood pressure and improved healing times.	27, 55, 78

Note. UV = ultraviolet.

benefits from nature (Table 1), and these examples highlight the critical need for collaborative research involving health scientists, health practitioners, ecologists, and others to link each step of the causal pathway between nature and health outcomes. Such collaborations are currently rare perhaps because researchers face a range of challenges working across disciplinary divides, including communication barriers[79] and perceptions of limitation to academic career options.[80]

However, a pioneering study that does take an interdisciplinary approach to examining a nature–health connection shows evidence that links specific measures of environmental diversity (including plant species diversity) around the home and allergy incidence in adolescents.[21] The study extends the hygiene hypothesis,[81,82] predicting that reduced contact with the natural world and the associated microbiota will lead to inadequate stimulation of immunoregulatory circuits.[71] A link was discovered by measuring variables at each step of the causal pathway, including plant and landscape diversity, microbial diversity in the soil and on people's skin, immune function, and finally allergic response. This study elegantly unites ecology and health science to test an a priori hypothesis, but it also reveals how simple, and perhaps counterintuitive, initiatives such as enhancing plant diversity around the home could reduce allergy prevalence.

NATURE AND HEALTH DISPARITIES

There is a growing body of evidence demonstrating inequalities in access to urban nature. Disadvantaged neighborhoods have repeatedly been found to contain less overall vegetation cover,[83–86] less public parkland,[87] fewer street trees,[88] and lower plant species richness and vegetation abundance.[89–92] In addition, although public green spaces are accessible to all, only a portion of the population commonly uses these spaces, and visitation is strongly influenced by factors such as gender, culture, and socioeconomic disadvantage.[93,94] This issue cannot be addressed by planning alone, but will require the use of community engagement or social marketing programs to connect people with their neighborhood green spaces.[66,95]

Disparities in access to nature can in part be driven by the greater cost of land in nature-rich suburbs,[96–100] but also by social factors that include different levels of participation in and preferences for neighborhood or yard greening activities.[84,101–104] Green space management can also differ along socioeconomic gradients; for example, tree removal to create the perception of safer spaces might be considered more important in disadvantaged areas where crime rates are higher,[105] and neighborhood class, status, and political power might also drive government investment potentially leading to better-quality neighborhood green spaces.[106–108] Reflecting these issues, in some instances, government tree planting efforts have been found to be focused within more wealthy neighborhoods,[108] and community uptake of tree planting schemes biased to more advantaged suburbs.[109]

Given the health outcomes that nature can deliver, inequalities in access and use could exacerbate social disadvantage.[106,107] As a consequence, policy initiatives that aim to improve the opportunity to access nature and the ecological characteristics of available green space, as well as community use of these settings could provide a cost-effective tool for enhancing health equality. These initiatives could be carefully tailored based on an improved knowledge of causality to meet the health needs of specific communities.

CONCLUSIONS

The potential health benefits from nature are diverse, with many direct and indirect pathways leading to physical, mental, and social health outcomes. We call for robust, hypotheses-driven science to help policymakers develop cost-effective nature-based solutions that meet the health challenges of a growing urban population. The correlative design of most previous studies, and continuing poor understanding of which components of nature deliver which health benefits, prevents truly effective integration of nature into health policy. As a consequence, urban planning generally takes a one-size-fits-all approach by setting broad provision-based targets and guidelines for urban green infrastructure.

We have shown here that there is sufficient foundational research to move beyond this by identifying a priori some of the causal pathways through which nature could influence health. Yet to optimize the potential health benefits from nature we now need a completely new research agenda founded on testing causality, and assessing the scale of the dose–response relationship between nature and health under different conditions. A key approach that will allow direct testing of causal pathways is controlled field studies, in which immediate and longer-term responses in both individuals and populations are measured in response to variation in natural features; this concept is similar to dose–response modeling.[110]

Causality may also be statistically inferred through observational longitudinal studies,[111] in which corresponding changes in nature and health outcomes are observed for populations or individuals. Close partnerships among ecologists, health scientists, and health practitioners, as well as psychologists, sociologists, landscape architects, and town planners, will be essential to capitalize on this opportunity. The reward will be cost-effective health policies that flexibly meet the needs of a range of communities and that also contribute to the environmental sustainability of our future cities. ■

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