Nature and Health

Terry Hartig,[1] Richard Mitchell,[2] Sjerp de Vries,[3] and Howard Frumkin[4]

[1]Institute for Housing and Urban Research, Uppsala University, SE-75120 Uppsala, Sweden; email: terry.hartig@ibf.uu.se

[2]Centre for Research on Environment, Society and Health, Institute of Health and Wellbeing, University of Glasgow, Glasgow G20 0TY, United Kingdom; email: Richard.Mitchell@glasgow.ac.uk

[3]Alterra/Cultural Geography, Wageningen University and Research Center, 6700 AA Wageningen, The Netherlands; email: sjerp.devries@wur.nl

[4]School of Public Health, University of Washington, Seattle, Washington 98195, USA; email: frumkin@uw.edu

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Abstract

Urbanization, resource exploitation, and lifestyle changes have diminished possibilities for human contact with nature in many societies. Concern about the loss has helped motivate research on the health benefits of contact with nature. Reviewing that research here, we focus on nature as represented by aspects of the physical environment relevant to planning, design, and policy measures that serve broad segments of urbanized societies. We discuss difficulties in defining "nature" and reasons for the current expansion of the research field, and we assess available reviews. We then consider research on pathways between nature and health involving air quality, physical activity, social cohesion, and stress reduction. Finally, we discuss methodological issues and priorities for future research. The extant research does describe an array of benefits of contact with nature, and evidence regarding some benefits is strong; however, some findings indicate caution is needed in applying beliefs about those benefits, and substantial gaps in knowledge remain.

Erratum

INTRODUCTION

The public health field views the natural environment with ambivalence. Infectious agents, extreme weather, and geological events regularly sicken, injure, and kill people, often en masse. Yet, people cannot remain healthy without clean air, clean water, food, and other resources provided as "ecosystem services." Enormous amounts of research inform these contrasting perspectives, describing how the natural environment harms humans, how health depends on the natural environment, and how human impacts on the natural environment rebound on health.

A theme that has become increasingly distinct over recent years concerns the natural environment, or "nature," perceived, valued, and engaged with as such, particularly in urbanized societies. This research focuses primarily on benefits of contact with nature. Key segments of this literature are young, but central ideas, such as the link between vegetation and air quality, have ancient provenance in the public health field (82). Interventions prompted by those ideas, such as urban parks, have long remained in place, presumably because the public has enjoyed them and believed in their salutary value. The recent research tests such beliefs, and it encourages more nuanced theoretical and practical consideration of nature-health relations.

In this article, we review work done in recent decades to better characterize the health benefits of contact with nature. We do not cover this body of work comprehensively, but instead we focus on nature as represented by aspects of the physical environment relevant to planning, design, and policy measures that target broad segments of urban populations. We touch on clinically oriented work on contact with nature in therapeutic contexts, but we do not discuss benefits of companion animals, which may be taken as representations of nature (42; however, see 6). Although the core ideas we discuss have a durable legacy in public health practice, the topic has not previously been the focus of an *Annual Review of Public Health* article (however, see 44, 80).

Below, we examine the concept of nature, consider reasons for the current expansion of research, and provide a "review of reviews." We then review research on pathways involving air quality, physical activity, social cohesion, and stress reduction. Finally, we discuss methodological issues and priorities for future research.

DEFINING "NATURE"

In an objective sense, "nature" as used here refers to physical features and processes of nonhuman origin that people ordinarily can perceive, including the "living nature" of flora and fauna, together with still and running water, qualities of air and weather, and the landscapes that comprise these and show the influence of geological processes. As such, "nature" overlaps substantially with "natural environment," an environment with little or no apparent evidence of human presence or intervention, and the two terms have been used interchangeably.

In practice, however, much research does not accept exclusion of the artificial as a basis for defining nature or natural environment. The nature of interest is often situated in built environments, as with indoor plants and street trees. Similarly, allotment (or community) gardens and urban parks comprise natural features, appear natural, and provide opportunities to engage with and follow natural processes, but they are typically designed, constructed, regulated, and maintained. Research has also acknowledged that a person may experience nature as such when viewing natural elements or landscapes from a building or vehicle, in photographs and films, or in virtual reality setups.

The term "urban nature" is instructive. It admits the presence of nature even in those human environments that some consider the antithesis of the natural. Yet, just as it puts the urban and natural together, it also sets them apart. It exemplifies how contacts with nature in an urbanized

society occur within a frame of reference shaped in an everyday life oriented in various ways to the society's urban circumstances.

The term "nature experience" is used in some segments of this research to emphasize the subjective perception and evaluation of relevant environmental features (67). It is, however, not a purely individual subjectivity, nor is it fixed. An individual's experience of nature occurs within and carries further the long-running exchange between the society and its environment (48).

Nature experience: the subjective experience of nature as such

In sum, although nature has a wide variety of objective referents, it is also experienced subjectively and is effective as a social construction (for further discussion, see 106). Accordingly, researchers represent nature with diverse physical and spatial variables, encountered in diverse activity contexts. Some also apply measurement, analysis, and design strategies to tap into the subjective experience of the environment. Because opportunities for contact with nature, ways of encountering nature, and experiences of nature vary across sociocultural contexts, researchers have examined variation in outcomes not only among individuals within given populations, but also across populations (108).

SOME REASONS FOR THE CURRENT RESEARCH EXPANSION

Growth in this field of research is shown clearly by the increase in publications. For example, a search in the Web of Knowledge on just one term, "greenspace and health," yielded 2 hits for 1990–1999, 34 for 2000–2009, and 45 from 2010 to June 2013.

Why is this expansion occurring? Motives for involvement in the field vary. Some work reflects concerns that urbanization, environmental degradation, and lifestyle changes are quantitatively and qualitatively diminishing possibilities for human contact with nature. For example, dense urban settings, if poorly designed (without accessible green space), may reduce opportunities for stress-reducing nature contact as well as increase exposure to environmental stressors (53). Other work considers nature as just one aspect of the physical environment that is potentially beneficial for health. For example, epidemic obesity in some countries has focused attention on sedentary lifestyles and environmental supports for physical activity, including but not limited to nearby parks (24). In general, the research aims to inform practical measures that directly or indirectly involve access to nature, including provisions for housing, transportation, and recreation.

Change in thinking about health has also enabled expansion of the research field. With the epidemiologic transition to chronic, lifestyle-related diseases as the major causes of mortality, biopsychosocial explanation (33) came to compete with the biomedical model, and constructs such as "psychological stress" and "social support" came into widespread use. This development has suited a field populated mainly by people trained in disciplines (e.g., human geography, environmental psychology, social epidemiology) and professions (e.g., outdoor recreation management, landscape architecture, urban forestry) that take interest in how people perceive, interpret, evaluate, and act on the environment. The conception of health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (138, p. 100) has also been influential for its heuristic value and as a basis for action. By acknowledging the positive, multidimensional character and subjective aspects of health, this concept supports the involvement of a wide variety of actors in efforts to understand and support health, including but not limited to those trained to treat symptoms of ill-health (132). Research in the field accordingly represents health in many ways, not only with regard to forms of morbidity (86), causes of mortality (94), and longevity (119) but also with regard to self-reported health (26) and diverse intermediate outcomes involving different pathways, such as beneficial change in emotional and physiological markers of stress measured during visits to natural areas (3, 49).

Methodological and conceptual advances are also feeding the expansion of the field; old and new topics are being studied with a range of new tools. For example, beliefs about stress-reducing effects of park visits are widespread and long-standing (101), but experimental testing of such effects is a relatively recent activity (52, 125). These small-scale experimental demonstrations of pathway plausibility informed the first large-scale epidemiologic studies to assess associations between contact with nature and health (26, 87, 93). Those studies used resources and techniques that only recently became available. For example, they used land-use data extracted from satellite images with digital technologies to describe the spatial extent of different kinds of nature accessible to the given individuals and groups in their residential contexts.

Having considered some of the developments in societies, sciences, and professions that have motivated and enabled the recent expansion of this field, we turn now to examine the research in more detail, starting with previous efforts to review the literature.

REVIEW OF REVIEWS

Many review articles on nature and human health have been published in recent years. Assessing them is one means of summarizing the state of the field in terms of what is known and the quality of the research. In April 2013, we undertook a systematic search for reviews. We used Medline and all Web of Knowledge databases to identify peer-reviewed papers, sought nonindexed, non-peer-reviewed (gray) literature, and online reviews via Internet searches, and examined citation lists of already identified reviews. We included review articles or reports relevant to relationships between nature and human health and well-being. Inevitably, because the topic boundaries of nature and health are fuzzy, relevance was sometimes difficult to establish. For example, reviews on environmental correlates of physical activity often include access to urban parks or trails among many other environmental characteristics, but they may not focus on natural environments. We identified 59 relevant reviews at the time of the search (see **Supplemental Material**. Follow the **Supplemental Material link** from the Annual Reviews home page at **http://www.annualreviews.org**). Of the peer-reviewed articles, most appeared in journals concerned with public health or environmental planning.

Supplemental Material

The reviews varied considerably in methodology and guiding aims. We observed three broad search-and-synthesis approaches: (*a*) narrative reviews, not clearly based on a systematic literature search ($n = 24$); (*b*) narrative reviews based on a systematic literature search or comprehensive case identification ($n = 13$); and (*c*) full systematic reviews based on an exhaustive literature search ($n = 22$). The reviews tended to have one of four general aims. First, systematic reviews sought to collate and synthesize all evidence for the effects of specified contacts with nature on specified markers of health (e.g., 2, 123). Second, summary reviews often aimed to introduce the field, explain its concepts and the mechanisms by which natural environments might affect health, and then set out some evidence for effects (e.g., 54, 89). Some were published as gray literature and had been commissioned by governmental or nongovernmental agencies. A third group included what might be labeled "flag-waving" reviews (e.g., 42, 95). These were aimed at introducing the topic to a new audience and were often relatively brief. Fourth, and fewer in number, were conceptual reviews, methodological reviews, or those proposing new theoretical perspectives (e.g., 8, 79).

Reviews also varied by the environments and/or pathways to health discussed. Physical activity had the most dedicated coverage as the focus of 18 reviews (e.g., 65, 90). Mitigation of poor air quality/urban heat problems and physiologically/psychologically restorative effects also had dedicated reviews (e.g., 12, 15, 19). Twenty-six of the reviews addressed multiple mechanisms. The reviews covered a wide range of natural features and environmental categories, including

indoor plants (16), urban parks (90), and forests (22), but coverage was uneven. Urban parks were the most commonly considered setting. Two categories of environments were conspicuously underrepresented or absent; rural areas had just one review (41), and there were no review articles about gardens or allotments or community gardens other than those used for therapeutic purposes. Also, very few reviews focused on population subgroups. Children were the most commonly considered subgroup (e.g., 91, 96). We found no reviews dedicated to differences in relationships between nature and health by gender, ethnicity, or socioeconomic position.

Given this variety in method, aims, and focus, we find it interesting that there was strong agreement about the methodological state of the art. Reviews commonly concluded that the field remains dominated by observational study designs. Reviews agreed that too few primary studies have been carried out in a consistent and rigorous way to establish the causality of relationships between contact with nature and health. They agreed, too, that few primary studies have explored how effects may vary by population subgroup, by type of natural environment, or by type of contact with nature. Many reviews commented that consistent and objective measurement of both exposure to nature and health-related outcomes remains elusive.

We identified three weaknesses in the reviews with specific relevance to this field. First, search strategies did not always address the variety of environments or settings that count as "natural." It is necessary to enter multiple terms into the literature search to avoid missing important work. For example, urban parks may be described by one or more of park, green space, greenspace, green areas, open space, recreational space, natural space, natural environment, etc. Building a review of relevant literature on a search for "green space" or "park" alone, for example, is inadequate.

Second, reviews from individual-based disciplines such as psychology tended to ignore evidence from population-based disciplines such as epidemiology, and vice versa. A great strength of this field is that evidence exists to describe benefits of contact with nature at multiple levels, from laboratory experiments tracking individuals' physiological reactions to viewing natural scenes through to studies of differences in population mortality rates between more and less green cities. Each level and scale of study provides important components in understanding what contact with nature can and cannot do for human health.

Third, the variety of health outcomes used in primary studies was not well addressed. When reviews try to synthesize results from outcome measures that are sensitive to contact with nature in different ways, and for different durations, messages become clouded. The pooling of results from heterogeneous outcome measures may be motivated by a lack of multiple studies using consistent measures and study designs. However, failure to appreciate differences among outcome measures leads to mischaracterization of the evidence base. Heterogeneity in outcome measures used in primary studies perhaps explains the relatively small number of reviews that attempted a pooled analysis. The body of reviews consequently tells us little about effect size.

Overall, the reviews generally agreed that beneficial effects from contact with nature do occur and that these effects are plausibly connected to the mechanisms proposed in guiding theory. However, most of the evidence covered by the reviews related to intermediate health-related outcomes such as amount of physical activity, amount of social contacts, changes in physiological activity (e.g., cardiovascular, neuroendocrine, and musculoskeletal changes characteristic of stress reduction), changes in emotional states (e.g., increased happiness, decreased anger), and changes in cognitive capability (e.g., performance on standardized tests of executive attention) rather than to disease states or measures of mortality. The reviews found less evidence that traced full pathways from contact with nature, to measures reflecting the operation of the given mechanism(s), and on to longer-term outcomes. Thus, it is unsurprising that the reviews generally suggest that the evidence is not yet good enough to say when, where, and for whom given effects will occur or how large or long-lasting they will be.

PATHWAYS THROUGH WHICH CONTACT WITH NATURE RELATES TO HEALTH

PM: particulate matter

VOC: volatile organic compound

Contact with nature may affect health via multiple pathways. Pathways that have received relatively large amounts of research attention involve air quality, physical activity, social cohesion, and stress reduction. We describe each of these pathways and indicate some of the complexities involved in drawing conclusions about its role, including variation in association across people, activities, and characteristics of the nature under study. The pathways emphasize different aspects of nature, as physical environment, as setting for (individual and social) behavior, and as experience. Contact with nature involves all these aspects, so multiple pathways are likely to be engaged simultaneously and affect one another, a point to which we return at the end of this section. The different pathways and possibilities for effect modification by individual or contextual variables are illustrated in **Figure 1**.

Air Quality

Trees, shrubs, and other vegetation may affect ambient air quality and, through it, human health and well-being. There are both positive and negative impacts. Trees and other vegetation may reduce levels of some pollutants, including gases and particulate matter (PM), but they may also contribute to air pollution by releasing hydrocarbons. Some trees and plants release pollen, aggravating allergies. Finally, trees improve air quality indirectly when they cool urban environments and reduce building energy demand.

Trees and other vegetation can reduce levels of gaseous air pollutants [e.g., ozone, oxides of nitrogen (NOx), oxides of sulfur] and PM (37). For gases, the primary mechanisms of action are uptake by leaf stomata, absorption, and adsorption to plant surfaces. PM removal occurs through deposition on leaves and other plant surfaces (7). However, most PM is resuspended to the atmosphere, washed off by rain, or dropped to the ground (100). Empirical studies (e.g., 34, 113) and modeling studies (e.g., 103, 120) suggest that urban tree canopy generally reduces air pollution levels by no more than a few percentage points, and often far less, although some results suggest more efficient removal of PM (59, 63) and certain volatile organic compounds (VOCs) (70). Because trees may reduce air movement, especially in restricted spaces such as urban "canyons," they may impede the localized dispersion of pollutants. Local factors such as the density, species composition, and age of the tree canopy, the concentration of air pollutants, and the length of the in-leaf season influence the extent of pollutant removal.

Plants may also affect indoor air quality—an important observation because people in developed nations may spend as much as 90% of their time indoors. VOCs such as benzene and formaldehyde may derive from furniture, carpets, cleaning agents, paint, and other sources. Indoor plants, especially such species as English ivy and spider plant, have been shown to reduce levels of many VOCs (81, 140). Bacteria in the soil may account for some VOC scavenging attributed to the plants (102).

In contrast to pollutant removal, trees can also be a source of hydrocarbons, including isoprene and terpenes, with considerable variation by species (9). These biogenic hydrocarbons may function as precursors of ozone and secondary organic aerosols (20, 74). Modeling studies have assessed the relative contribution of biogenic emissions to pollution levels (e.g., 112). Results vary depending on the species of trees in a canopy, local atmospheric chemistry (especially levels of other precursors, such as NOx), local weather, and other factors.

Trees, grasses, and other plants release pollens, which can aggravate allergies and asthma in susceptible people (18, 27). The culprits vary with geography but include ragweed, grasses (e.g., Timothy, Bermuda, bluegrass), and trees such as catalpa and walnut. In cities that have favored

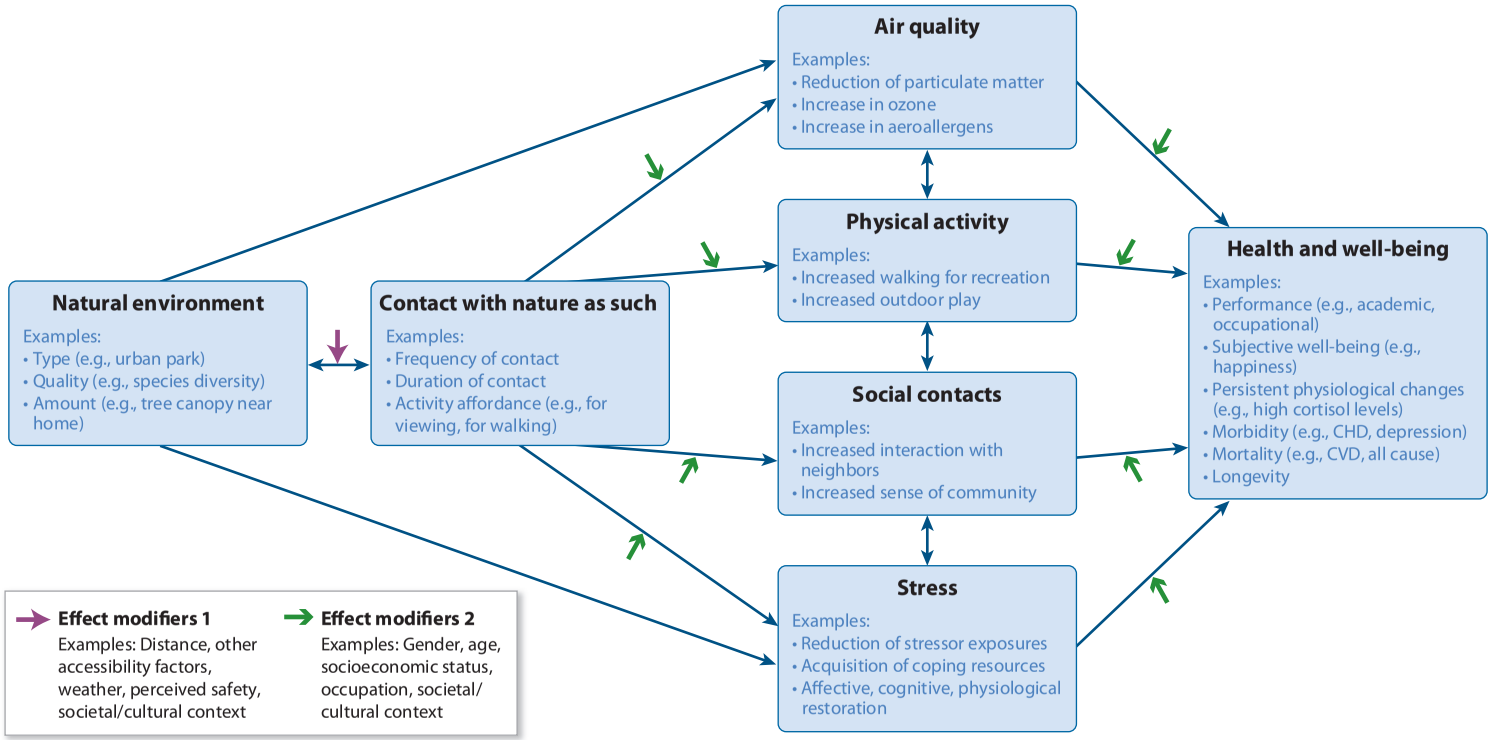

Figure 1

Some pathways through which the natural environment can affect the health of broad segments of populations. Four of the pathways go through contact with nature, whereas two others go directly from the natural environment to air quality and stress, respectively, implying that the natural environment may affect health without an individual or group consciously engaging with nature as such. Associations between variables at the different steps in a given pathway are subject to modification by characteristics of the people or the context. The two-headed arrow between the natural environment and contact with nature acknowledges that these are joined in a reciprocal relationship. The two-headed arrows between the variables designating pathways (air quality, physical activity, social contacts, and stress) also speak to their reciprocal relatedness; however, each may be related with all the others and not only with the one adjacent. Abbreviations: CHD, coronary heart disease; CVD, cardiovascular disease.

trees that are heavy pollen producers, the health impact may be especially significant (19). A study of African American and Dominican children in New York City found a small but significant association between tree canopy extent and asthma and allergic sensitization (83). Hence, in some circumstances, the allergenic role of trees may eclipse their ability to improve health by reducing air contaminants.

Vegetation, especially trees, may also indirectly benefit air quality. During warm weather, trees reduce summer air conditioning demand by shading and hence cooling buildings and through the cooling effects of evapotranspiration. This effect, in turn, reduces energy demand, which, in areas served by coal-fired power plants, reduces air pollution derived from coal combustion, though not necessarily at the same location (1). During cold weather, the reverse can happen. In a simulation study in Sacramento, trees reduced the need for cooling energy in summer about three times more than they increased the need for warming energy in winter (114). The monetary benefits of energy savings related to trees may exceed those of the pollutant removal (13).

The overall impact of vegetation on air quality is therefore a function of several processes, operating in opposing directions: hydrocarbon emissions, pollen production, pollutant uptake, and effects on energy demand. Careful selection of species, design of planting configurations with regard to wind, shade, and other impacts, and maintenance of urban vegetation can optimize the beneficial effects on air quality (30, 100).

Physical Activity

Physical activity promotes physical and mental health across the life span (10, 61). Recent evidence suggests that the health benefits of increased physical activity are largest among those who were initially doing the least (104). The outdoor environment may influence how physically active an individual is by offering suitable spaces for certain types of activities. It may also attract people outdoors because of the experiences it offers. Such outings ordinarily entail some form of physical activity, usually walking.

An important precondition for the use of natural environments for physical activity is individuals' (perceived) safety (62). Although there are possible negative effects associated with physical activity (e.g., sports injuries) as well as with being in a natural environment (e.g., Lyme disease from tick bites), most of these effects are not specific to physical activity in a natural environment.

Green space is only one part or aspect of the physical environment relevant for physical activity. Which environmental characteristics promote or hamper physical activity may depend strongly on the type of activity at hand (5). Three broad activity domains may be identified: work (including study), active transport (walking, cycling), and leisure (recreation, sport). Within the work domain, the greenness of the setting is thought to be of little importance for the amount of physical activity. The same is not true for active transport. Natural features may lead people to favor walking or cycling over other transport modes by making routes to destinations more attractive; however, distance to destination, availability of suitable infrastructure (e.g., sidewalks, bicycle paths), and safety are more important factors (55). The evidence for association between green space and active transport (walking and/or cycling) is mixed, and this heterogeneity has been well summarized by recent systematic reviews (40, 78). Reasons for (noncausal) negative associations may be that large amounts of green space tend to go together with (*a*) greater distances to destinations, (*b*) higher levels of car ownership, and (*c*) better availability and lower cost of car parking spaces near one's home (28, 55).

The importance of natural environments for fostering physical activity may vary by population subgroup. Children are perhaps the most commonly studied subgroup in this context, but again results are mixed. In one review (29), ~40% of the studies in which environmental characteristics

were objectively measured showed park access or vegetation to be positively associated with children's physical activity levels; in the other 60% of the studies, no association was observed. A further systematic review (35) concluded that for (young) children the safety of the environment as perceived by their parents was an important moderating factor. Results from studies of older people are also mixed; two recent systematic reviews arrived at different conclusions. One (128) reviewed studies on the physical environment in general and concluded that there was no clear relationship between green space (and most other physical environmental characteristics) and physical activity of older people. The other specifically focused on green space, however, and it observed that seven out of eight studies showed a positive relationship between the greenness of the living environment and physical activity levels of older people (17). It also concluded that the perception of safety is an important moderating factor.

Relatively little attention has been paid to the relevance of specific environmental characteristics, such as the type of greenery or the quality of the open space. Results are again mixed. One study (46) concluded that very good access to large, very attractive public open space was associated with higher levels of walking. Another (56) by contrast observed no relationship between access to large, high-quality urban green spaces and recreational physical activity. A third study (25) observed a relationship of quality (but not quantity) of streetscape greenery with "green" activity, though not with total physical activity. Finally, recent results suggest that community gardening is associated with a lower body mass index (141).

Given that physical activity is assumed to be an important pathway joining nature with health, we find it surprising that few studies have formally investigated the extent to which any association between nature and health might be mediated by physical activity levels. Of four studies done (25, 88, 109, 118), only one (118) concluded that physical activity (more specifically recreational walking) was indeed an important mediator.

Finally, we note that most of the studies referred to in this overview have been cross-sectional in nature. Hence, the direction of observed relationships remains open to alternative explanations. For example, some people may choose a highly car-dependent (and presumably more green) living environment because they are not inclined to be physically active anyway (32).

Social Cohesion

Much as for physical activity, abundant research has documented positive associations between social relationships and health and well-being (57, 97). Such salutary associations have also been observed for positive relationships specifically within the neighborhood (110). A variety of terms have been introduced to reflect the potential value of social relationships in this context, including social capital, social support, social cohesion, and sense of community. Although these terms are often used interchangeably (4, 110), we draw a distinction here between social capital and social cohesion. Social capital comprises primarily those resources available to an individual through his or her social connections, which may be activated in times of need. In contrast, social cohesion refers to shared norms and values, the existence of positive and friendly relationships, and feelings of being accepted and belonging (cf. 36). We prefer to use the term social cohesion here because it is more a characteristic of neighborhoods than of individuals (4) and so more likely to be influenced by physical characteristics of the neighborhood, such as the availability and quality of green space and natural elements.

Unlike physical activity, the environmental correlates of social cohesion have received little research attention thus far. Generally, the few studies available suggest a positive relationship between social cohesion and natural environments (25, 38, 85, 118). Sugiyama et al. (118), for example, found perceived social coherence and local social interaction to be associated with the

perceived greenness of the neighborhood. De Vries et al. (25) found an association between streetscape greenery and perceived social cohesion at the neighborhood scale, both for the quantity and, even more strongly, for the quality of greenery.

Social cohesion within a neighborhood does not lend itself to experimental research, which makes it difficult to determine whether relations with environmental features are causal. A few studies have, however, taken advantage of circumstances that likened a natural experiment. Researchers in Chicago (77) took advantage of quasi-random assignment of public housing residents to dwelling units in architecturally similar high-rise buildings with varying amounts of vegetation outside. They found a positive association between the presence of trees and grass on the use of common spaces and informal social contact with neighbors. Moreover, the relationship between greenery and social contacts appeared to be mediated by the use of the common spaces.

The research in Chicago (77) also showed that social contact was positively related to one's sense of safety. Subsequent studies showed that residents with more trees and grass around their buildings displayed less aggressive behavior, and their buildings were associated with fewer crimes (75, 76). More recent research suggests similar positive effects of greening vacant lots, especially a reduction in gun assaults and disorderly conduct (14).

Other attributes of the environment may moderate any association between natural features and social cohesion. Arguably, local parks must be well maintained and provide attractive recreational facilities to realize their full potential in developing social ties (71). Although green space generally is positively associated with feelings of safety, in dense urban areas enclosed green spaces may reduce such feelings (84). Similarly, trees in the public realm have been associated with reduced crime rates, but small trees on private lots have been associated with increased crime rates, presumably because these trees make it more difficult to observe criminal activity (31). Some natural settings, such as community gardens, incorporate social ties almost by definition. In one study, older allotment gardeners reported having more contacts with friends and felt less lonely than did nongardening neighbors in the same age category (131).

The question remains whether social cohesion, sense of safety, aggressive behavior, and crime rates mediate an eventual relationship between contact with nature and health. Results from a few cross-sectional studies bear on this point. One found that social cohesion partially mediated the relationship between perceived neighborhood greenness and mental health (118). Another concluded that feelings of loneliness and perceived shortage of social support partially mediated the relationship between the amount of green space within one kilometer and overall health (85). A third found that social cohesion mediated relationships between quantity and quality of streetscape greenery and both overall health and mental health (25). In contrast, Francis et al. (39) found neither sense of community nor social support to be an important mediator of the relationship between the quality of public open space and mental health. No studies were identified on mediation by aggressive behavior, fear of crime, and/or crime rates.

Stress Reduction

By helping people maintain adaptive resources needed to meet the demands of life, nature can reduce risk of illnesses involving chronic stress, as well as promote a range of intermediate outcomes such as increased subjective well-being. It can do so in two general ways. First, natural areas and features can reduce exposure to challenging environmental conditions by increasing distance to stressors and/or decreasing their perceptual salience. For example, green spaces between residences and heavily trafficked roads can reduce occupant noise annoyance (99), vegetation can conceal displeasing structures (115), and landscaping around housing can help residents maintain privacy and avoid feelings of crowding (23).

Second, nature can help people restore their adaptive resources. Escape from physical and social stressors has long been described as an important motive for recreation in natural areas (58, 72). Nature's restorative quality does not, however, depend only on an absence of stressors; its restorative quality is also defined in positive terms. Another persistent motive for outdoor recreation has been appreciation of nature—for beautiful scenery, symbolic qualities, and other valued attributes (72). Push and pull motives also work in tandem in contexts other than outdoor recreation, notably the residential context. For example, residential location decisions commonly reflect efforts to both minimize stressful exposures and enhance access to restorative amenities, including green (or blue, i.e., water) areas (51).

ADD: attention deficit disorder

This motive combination appears in two theories about how nature can promote more rapid and complete restoration than other environments can. They offer contrasting views on how restoration can proceed once a person has gained psychological distance from threats and other demands. Psychoevolutionary theory holds that, for a person experiencing acute stress, nature contact can very rapidly evoke positive affect, which in turn blocks negative thoughts and feelings and fosters reduction of physiological activation (126, 127). Evolution purportedly conserved this functional aesthetic response because more rapid recovery from acute stress would have helped proto-humans better prepare for the next survival task. In contrast, attention restoration theory holds that effortless attention engaged by intrinsically interesting aspects of nature enables rest for a fatigued neurocognitive inhibitory mechanism engaged when willfully directing attention (67, 68). People must inhibit task-irrelevant stimuli as they direct their attention at work and in many other circumstances. Fatigue of this directed attention capability occurs commonly, undermines effective action, and can increase susceptibility to stress (68).

Informed by one or both of these theories, true and quasi-experiments done in laboratory and field settings have assessed diverse affective, cognitive, and physiological effects of more and less natural comparison conditions, realized over varying but generally brief time spans after a naturalistic or experimental induction of a need for restoration. Published studies generally report some restorative advantage of nature, and by 2004, reviewers had judged the evidence for restorative effects of nature to be strong (54). More recently, methodological heterogeneity led other reviewers (11) to include only 3–6 studies in quantitative syntheses for each of several outcomes. They concluded, nonetheless, that the available studies provided reliable evidence of reductions in self-reported anger, fatigue, anxiety, and sadness and an increase in feelings of energy. They also found tentative evidence of enhanced attention. Conclusions regarding physiological effects were limited by a lack of studies that had the desired design features. Studies done since that 2010 review have further expanded the body of experimental evidence in several directions: additional comparison conditions [e.g., more or less open vegetation (45); encountered in different ways, e.g., work site desktop relaxation packages (60)], alone or in company (64), and in additional subpopulations [e.g., children with attention deficit disorder (ADD) (121), with effects registered using additional measurement techniques (e.g., cortisol; 129)].

Other research assumes cumulative health effects of more effective restoration on many occasions over time. That work is bolstered by studies that situate repeated contact with nature into an ongoing process of self-regulation. Such studies recognize that some people learn that natural settings are more likely than other settings to be restorative. Over time, they apply this knowledge to better manage adaptive resources such as attentional capacity (69, 73, 116). When and how that learning begins remain understudied, but childhood experience appears influential for environmental attitudes measured in later life (133, 136). Some research does suggest that restorative childhood contact with nature can cumulatively provide benefits with far-reaching developmental significance. Contact with nature may for example improve attentional function in children with ADD (121) and enhance self-discipline in children without a diagnosis (122).

Observational studies commonly cite nature's cumulative stress-reducing or restorative effects as one plausible pathway by which residential green space might affect perceived health (26, 87), diverse forms of morbidity (86), and death from circulatory disease and other causes (94). To date, however, most studies with individual data have not directly addressed a stress-reduction pathway owing to a lack of measures suitable for assessing mediation. One early quasi-experiment did however assess mediation with reference to attention restoration (76), and some recent surveys have begun to address this issue with self-report measures (25, 117). Another study has considered variation in the level of cortisol as a biomarker of chronic stress in members of a community sample living in more or less green circumstances (134); such a measure could serve tests of mediation of the effect of nature on stress-related illnesses.

Some studies have framed nature as a stress buffer, which has entailed estimating the interactive effect of stressful demands and access to nature on some health outcome. Several studies focused on nature in the residential context are illustrative. In a study done in rural New York state, conflicts at school experienced during the preceding three months were less strongly associated with psychological distress in children who had more nature in and around the home (135). In a Dutch study, the relationships between stressful life events in the previous three months and both health complaints and perceived general health were weaker among those with more green space within 3 km of the home (130). In an ecological study covering the population of England, high income deprivation had a weaker association with all-cause and circulatory disease mortality among people living in areas with relatively large amounts of green space (94).

In sum, substantial evidence speaks to the potential benefits of contact with nature for avoiding health problems traceable to chronic stress and attentional fatigue; however, the greater part of this evidence concerns the short-term restorative benefits of single encounters with or experiences in nature.

The Pathways Intertwine

Discussions of air quality, physical activity, social cohesion, and stress-reduction pathways emphasize different aspects of nature: as physical environment, as setting for (individual or social) behavior, and as experience. Contact with nature involves all these aspects, so multiple pathways are likely to be engaged simultaneously, as illustrated in **Figure 1**.

Most individual studies have focused on one particular pathway from nature to health, but some research has addressed combinations involving two or more of them. Much of this work has recognized links between physical activity and stress reduction. People commonly engage in physical activity not only or even primarily because it will serve their health in the long run, but also because it helps them to feel good in the short run, sometimes by reducing tension and stress. Conversely, people who want to enter a natural environment for restoration ordinarily must engage in some form of physical activity to do so. Accordingly, experiments have found "green exercise" more psychologically beneficial than the same exercise in settings with relatively little nature (92, 105). Thus, being active in natural settings may yield health benefits over and above the benefits of physical activity in other environments (for a meta-analysis, see 123). Conversely, a person walking or running along city streets may have to endure aversive conditions that reduce the benefits of the activity itself (49).

Multiple pathways may be purposefully combined in cultural practices that regularly bring people in contact with nature. For example, community gardening may promote social contacts during moderate physical activity that also supports restoration from stress associated with work or other demands. The Japanese practice of Shinrin-yoku, or forest-bathing, involves beliefs about the

salutary values of certain substances in the air, and it entails behaviors that ordinarily promote stress reduction (e.g., distancing oneself from everyday demands, adopting a meditative stance) (124).

Some cultural practices that engage multiple pathways may however not be salutary for all population subgroups. For example, in some countries, many households maintain a simple, inexpensive leisure home in the countryside, to which family members ordinarily travel together during vacation periods; however, as a domestic setting, the leisure home may also impose unwanted demands and on some household members more than others. Swedish research found that, after several years of follow-up, employed men who owned a leisure home had lower odds of retiring early for health reasons (50); however, this prospective association did not hold for women. Indeed, among highly educated and highly paid women, the likelihood of early retirement for health reasons was greater if they also owned a leisure home. Other studies have also indicated a potential gender difference in the nature-health relationship (e.g., 107).

METHODOLOGICAL CHALLENGES

In addition to the usual methodological concerns in experimental and epidemiologic research, we must tackle a litany of specific methodological challenges if we are to develop our understanding of the degree to which, how, and under which circumstances contact with nature affects human health and well-being.

Measuring Exposure to Nature

Contact with nature challenges definition and control in field and laboratory experiments, and it is even more difficult to assess in free-living populations. Studies at population level typically assess exposure in one of three ways: assessments of exposure by how much nature there is in, or close to, the participants' area of residence; survey questions about how much time, and/or how often, people visit natural environments; and objective measures of contact via GPS (global positioning systems) technology. Each method has problems; that people live near natural spaces, report visiting them, or position themselves spatially within them does not mean that individuals actually have had contact with nature in a way that affects their health. None of these measures includes visual contact with nature from, for example, windows at home or in the workplace, which may also have beneficial effects (66). Furthermore, these measures typically miss fine details of exposure that may be important, such as the timing of exposure (e.g., for many environmental exposures, specific windows of vulnerability exist across the life span), the seasonality of exposure (e.g., the role of deciduous trees being in leaf), the quality of the nature (e.g., area in mature trees versus immature trees versus shrubs versus lawn), and the duration of exposure.

Measuring Outcomes

The other end of the equation between natural environment and health is the assessment of health itself. Plausible health impacts are varied and multiple, positive and negative, psychological and physiological, short term and/or long term. This plurality means many different health measures can be used, which, in turn, makes it difficult to achieve a coherent body of research. There is a particular challenge in bridging what we know about effects of contact with nature from small-scale, shorter-term experimental studies and what we might expect to observe as effects in the real world at the population level. For example, it is difficult to determine what the fall in blood pressure on viewing nature, established in experimental studies, might mean for rates of heart

disease among regular visitors to national parks. There is no simple solution to this challenge and no one clearly superior set of instruments or measurements that are suited to use in all settings and studies.

Understanding Mechanisms

Understanding how any relationship between nature and health happens can aid interventions that promote possible benefits. It is also vital for specifying who might benefit most and least from the relationship. The challenge is that, as we have noted, the mechanisms by which nature might affect health are multiple and synergistic. They likely vary in significance within a single contact with nature, between contacts, across the life course, between population subgroups, between environment types and across cultures. Understandings of mechanisms being developed in the relatively controlled conditions of experiments should eventually help epidemiologists to form better hypotheses about the variation in associations they could expect at a population level.

Demonstrating Causality at a Population Level

Positive, short-term effects of contact with nature on affect, cognition, and physiology have been reasonably well established in laboratory and field experiments. However, cross-sectional designs still dominate studies of long-term health outcomes measured in populations. The vulnerability of these designs to confounding and reverse causality is a particular problem. The likelihood of contact with nature is strongly patterned by socioeconomic, ethnic, age, and cultural characteristics, which are, themselves, linked to health. Richardson et al. (108) provide a fine example of the potential for confounding factors to obscure relationships between green space and health at a population level.

Both experimental and longitudinal observational designs are potential routes to better evidence for a causal relationship among free-living populations. For studies of nature and health, however, both types of study impose specific challenges. Experimental studies at a population level are hard to perform. Manipulating environments or people is difficult and expensive. Scientists often must rely on public agencies or authorities to fund and deliver environmental changes, such as the creation of a new park or trail. It can also be difficult to establish and maintain control sites or populations, and opportunities to randomize the receipt of environmental interventions to different communities are rare. Useful results have emerged from quasi-experimental and before-after studies that capture some of the attributes of true experiments (14, 75). The timescale for effects is also often a constraint. Funding to follow-up intervention studies is rarely longer than 3–5 years, but effects at a population level (perhaps even intergenerational effects) may take longer to establish.

Research on nature and health has been undertaken within different scientific paradigms. Attitudes toward the level of proof for an association, indeed attitudes toward the very idea of "proof," vary between paradigms and are contested within them. Biomedical research, for example, often places great emphasis on low p-value thresholds for acceptance of an association. Frumkin (43) recently suggested, however, that the application of stringent p-value thresholds needs careful and explicit reconsideration in studies of nature and health. Moving from partial evidence to evidence-based recommendations regarding nature contact is a thorny problem.

For their part, existing panel or cohort studies that have good measures of health and well-being rarely also carry detailed information on contact with natural environments because this topic is relatively new to public health and epidemiology. Moreover, data sets that can also capture the change in or development of natural environments over time are rare.

Effect Size

Evidence suggests that contact with nature has a small effect on health and well-being in comparison to structural characteristics such as income, employment, or education, and behavioral characteristics such as smoking. The signal-to-noise ratio in population-level studies is often small, and these studies need to be well designed and of sufficient power to identify any benefits. This does not mean that such studies are not worth doing, however; a small beneficial effect on a large number of people is a large contribution to population health (111).

PRIORITIES FOR FURTHER RESEARCH

Throughout this review we have identified issues that warrant further research, and in the previous section we have identified methodological challenges that must be met. Here, we try to highlight some specific priorities for the field.

First, we see a need to seek, create, and take opportunities for population-level experimental studies when they arise, within an understanding of their limits. Doing so will assist in demonstrating the degree to which nature-health relations have meaning for population health. We should also work to incorporate questions about contact with nature in ongoing longitudinal studies and ensure that high-quality data on change in type, quality, and availability of nature are maintained into the future and created retrospectively for the past. These additions would permit studies consistent with both cohort and life-course perspectives on relationships between nature and health.

Second, research on which types of nature are relatively effective for particular outcomes, and which qualities of those types are highly relevant, may be more fruitful when guided by theoretical ideas about why a particular type or quality of that type is likely to contribute to a particular pathway to health. Natural elements that are effective in improving air quality are not necessarily the same as those best suited to improving social cohesion in a neighborhood or to promoting psychological restoration.

Third, with specific regard to the stress pathway, much work remains to be done to rigorously assess theoretical claims regarding the components of experience that sustain attention restoration and stress recovery. To what extent, for example, are beneficial effects dependent on gaining psychological distance from stressful demands versus engaging with positive aspects of the nature encountered? This work will be aided by, among other things, further development of measures of perceived restorative quality in environments, and experimentation that more directly addresses the interplay of stress recovery, attention restoration, and other possible processes through which adaptive resources become renewed (cf. 49).

Fourth, if we acknowledge the competing priorities for funding and investment in health and health care, some research on nature and health might gain from a health economics perspective. If contact with nature is cost-effective as a means to protect and improve population health, it should be resourced and prioritized in preference to other approaches. Arguably, doing so requires knowledge not only about the economic significance of the health benefits generated, but also about the "doses" of nature needed to generate those benefits at the lowest possible cost. Discussions of dose, however, can entail a variety of problems, such as trivialization of contact with nature through neglect of long-term consequences of particularly powerful forms of contact (e.g., life-changing wilderness experiences). The dose metaphor therefore must be handled with care (137). As with other health-related issues, economic analyses must extend beyond health impacts to account for other benefits. For instance, an urban park may offer not only health benefits, but also benefits such as stormwater management and enhanced property values.

Finally, variety between population subgroups in access to, use of, and responses to nature remains persistently underexplored. Spatial, social, economic, racial, cultural, and demographic differences in relationships between nature and health seem highly probable. It may be that relationships between nature and health are implicated in exacerbating or mitigating health inequalities between subgroups, for example. This potential should be thoroughly explored.

CONCLUDING COMMENTS

We have provided for a general public health audience an overview of research on how contact with nature relates to health in urbanized societies. We have not covered this body of work comprehensively, but instead have focused on nature as represented by aspects of the physical environment relevant to planning, design, and policy measures that target broad segments of urban populations, such as the availability of urban parks, the amount of green space in and near residential areas, and the preservation of peri-urban natural areas. Given our public health orientation, we have focused on the conditions of everyday life for the greatest part of the populations of interest. We consequently have hardly touched on the extensive literatures on wilderness experience (for reviews, see 72, 139) and contact with nature in the treatment and management of disability and illnesses such as depression (47) and breast cancer (21; see 2 for a review).

Despite such significant omissions, we trust readers will take away an appreciation not only of the diversity and complexity in forms of nature contact and potential benefits thereof, but also of the many challenges faced in characterizing those contacts and benefits. Taken together, the research reviewed does indicate that contact with nature can promote health. The evidence for some benefits, such as short-term restorative effects, is already quite strong. That said, nature contact should not be assumed always and automatically to be good for health; we have more to learn about for whom, when, how, and in which contexts it offers benefits.

Much also remains to be done to help those responsible for environmental policy, design, and management to make realistic assessments of what nature can and cannot do in their domain of activity. Part of this task involves explaining how health benefits might coincide (versus conflict with) other benefits, such as better stormwater management, species preservation, and carbon sequestration. If a particular form of nature contact shows small health benefits, interventions to promote it may still justify public investment if the health benefits combine with other benefits.

In closing, we recognize that many people speak of human-nature relations in moral/ethical and spiritual/religious terms with a view toward preservation of the natural environment. We respect such views. Our observations here regarding human health values should not be understood as the only or even the main bases for arguments regarding protection of habitats, species, and ecosystem integrity.

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