

interested community, to develop a land management and planning tool for the protection and future sustainable use of the region's wetlands.

Another example is that of one of the remaining perennial springs (La Carbonera) surrounding the city of Querétaro, located in a semi-arid region of central Mexico. Because the area's wetlands have been studied for several years, it was possible to rescue the spring, together with strong local stakeholder support and action. This is clearly a successful case in which locals worked closely with academics to achieve a common goal. This peri-urban spring has been managed, and the area is currently used to conduct recreational and educational activities while also contributing to the restoration of several critical ecological processes.

### Toward livable cities

The discipline of urban ecology has made great strides over the past three decades. To further our knowledge of urbanization's effects on people, biodiversity, and ecosystem processes, urban ecologists must shift from studying patterns to untangling the emerging mechanistic processes behind the reported patterns (15). However, it is also crucial to create the tools and procedures for transforming scientific knowledge into action. The need for these advances is pressing, as there is a growing discontent among urban dwellers worldwide, related to the erosion of their quality of life. Many urban dwellers are now calling for the creation of green, sustainable cities that are also healthy and resilient (16). Incorporating urban ecology principles into the design, construction, and management of cities will require the cooperation, alliance, and synergy of all stakeholders, thus reforming the way we conceive and prepare land to fulfill the needs of modern human agglomerations.

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### PERSPECTIVE

## Living in cities, naturally

Terry Hartig<sup>1</sup> and Peter H. Kahn Jr.<sup>2</sup>

Natural features, settings, and processes in urban areas can help to reduce stress associated with urban life. In this and other ways, public health benefits from, street trees, green roofs, community gardens, parks and open spaces, and extensive connective pathways for walking and biking. Such urban design provisions can also yield ecological benefits, not only directly but also through the role they play in shaping attitudes toward the environment and environmental protection. Knowledge of the psychological benefits of nature experience supports efforts to better integrate nature into the architecture, infrastructure, and public spaces of urban areas.

Crowding, noise, and other stressful urban conditions increase the risk of mental disorders such as anxiety and depression (1). However, urban areas also have environmental assets that support mental health. For example, parks, green spaces, street trees, and community gardens can facilitate physical activity, social contacts, and stress reduction (1, 2). How can psychological benefits from encounters with natural features and processes offset the psychological costs of other urban living conditions? Answers to this question will help improve the quality of life of today's growing urban populations (2, 3) (Fig. 1).

In his classic work on urban psychology, Stanley Milgram opened on a positive note, arguing that “cities have great appeal because of their variety, eventfulness, possibility of choice, and the stimulation of an intense atmosphere that many individuals find a desirable background to their lives” (4). He also saw that cities offer “unparalleled possibilities” for face-to-face contact and communication (4). Yet, when considering how psychology can contribute to understanding the experience of living in a city, he turned to the negative; he highlighted overload as a psychological concept useful for linking objective urban circumstances such as high population density to observable behaviors such as incivility. Such contrasting perspectives

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**Fig. 1.** Together with ecological benefits such as climate change mitigation and the protection of biological diversity, the renaturing of cities opens opportunities for people to engage with features and processes of the natural world; for example, when tending plants in a community garden.

continue to inform psychological research on urban life.

### Urban-rural differences in mental disorders

Numerous studies have suggested that urban living conditions undermine mental health, whereas conditions in rural areas support health. Peen et al. (5) performed a meta-analysis of 21 studies, done after 1985, that investigated the prevalence of mood disorders among non-institutionalized

adults in relatively affluent countries. They found that the odds of mood disorder were 28% higher in the urban areas than in the rural areas; however, the results were highly heterogeneous, perhaps because “rural” and “urban” were defined differently in different studies. They recognized the problem with integrating results when urban settings in some studies resemble rural settings in others.

Judd *et al.* (6) have argued that binary urban and rural categories are insufficient. Numerous environmental factors can affect the stress that people experience in urban and rural settings and, thus, the prevalence of disorders such as anxiety and depression. These include, for example, residential density, housing quality, air quality, transportation options, access to health and welfare services, and access to parks and green spaces. All of these factors might play a role in

Findings of urban-rural differences in mental disorders might be taken as warnings about the consequences of urbanization, but there is a risk of confusing cause and effect. The social, political, and economic forces that drive urbanization in a particular society may also generate mental illness through other mechanisms. For example, in some countries, many people have left rural areas for urban ones under threat of violence; this appears to have boosted the prevalence of major depressive disorder (7). Poor conditions in the spontaneous settlements they create may exacerbate the effects of victimization, disruption of social relations, and loss of traditional occupations, but urbanization itself is not the initial cause of disorder.

### Psychological benefits of nature experience

Research on the experience of nature also suggests that urban living conditions can undermine mental health, whereas relatively natural conditions can support it. The term “nature” means different things in different contexts. Recognizing personal and cultural aspects of the experience of nature, psychological research considers how different people encounter nature in diverse contexts, from viewing indoor plants in urban offices to walking in wilderness areas.

A significant portion of this research concerns the restorative effects of nature experience, such as regaining the ability to concentrate and reducing blood pressure after intensive mental work (3, 8). Theories about restoration describe how encounters with nature involve psychological distance from everyday demands and interested engagement with environmental features and processes. These components of restorative experience have counterparts in many analyses of why people engage in outdoor recreation, done in the United States and elsewhere since the early 1960s (8). Complementing what people have long said they seek through outdoor recreation and substantiating theoretical claims, laboratory and field experiments have repeatedly shown that spending time in natural environments or viewing scenes of nature can quickly help people to lift their mood, improve their ability to direct attention, and reduce physiological arousal to a greater degree than do urban streets and other comparison conditions (2, 8).

As in studies of urban-rural differences in mental disorders, comparisons of single examples of urban and natural environments have been crit-

icized for neglecting relevant forms of variation (8). Experimental evidence regarding plausible mechanisms has nonetheless encouraged large observational studies on urban green space and health. Such studies consider plausible cumulative effects of green space and greenery near an urban home. Most such studies focus on quantity, but some have also used quality indicators (9). Most of the observational studies have used a cross-sectional design, but recent longitudinal studies have enabled stronger inferences regarding beneficial effects of access or proximity to nature. For example, using 5 consecutive years of data for each of 1064 participants in the British Household Panel Survey, Alcock *et al.* (10) showed that those who relocated from a less green (58% local area coverage) to a more green (74% urban area) showed improved mental health over the next 3 years. In contrast, those who moved from more (74%) to less (59%) green urban areas showed a decline in mental health before the move, followed by a return to the pre-move baseline.

Much research on nature experience assumes that too few generations have passed for natural selection to shift the adaptedness of affective and cognitive functioning from the conditions of hominid evolution (8), and that humans are therefore poorly adapted to living in urban environments, broadly defined. This natural-urban antithesis neglects the fact that urban environments include settings that are supportive of human functioning; noisy, polluted, car-filled streets lined by anonymous towers are not representative of all urban possibilities. This false antithesis also neglects reasons why people gathered in cities millennia ago, and the consequences of that move for the interplay of natural selection and sociocultural development. Here too, the environmental categories and the urbanization process need closer examination.

### The design of cities and human-nature relations

Psychological research has substantiated longstanding reasoning about parks and green spaces as health resources for urban populations (8, 11, 12). This reasoning has guided the creation of parks in many cities, such as Central Park in New York and Mount Royal Park in Montreal. Extending such precedents, researchers, design professionals, citizen groups, and others are working together to create sustainable urban fabrics in our increasingly urbanized world. These efforts—under banners such as green urbanism, green infrastructure, biophilic design, and renaturing—seek a better synthesis of natural processes and ecosystem functions with architecture and urban infrastructure through acts of creation, preservation, and ecological restoration. Such efforts are needed for psychological as well as ecological purposes. The evidence mentioned above and more like it warn against assuming that people can simply adapt to increasing urban density and its concomitants without negative consequences for health and well-being.

By providing opportunities for people to experience nature in cities and to experience cities



**Fig. 2.** People living in cities can encounter nature in the context of many different activities. Their experiences can enhance their development, health, and well-being, and they can shape their attitudes toward the environment and environmental protection.

whether a given individual develops a disorder, but they may do so in different ways in different combinations. Together with individual vulnerabilities and broader contextual characteristics, research must consider the independent and combined effects of these factors in order to elucidate how specific urban conditions may undermine or support mental health.

as natural, such efforts can shape attitudes toward the environment (Fig. 2). People in increasingly large and dense urban areas may have few or no contacts with the natural world in everyday life. Environmental generational amnesia refers to the psychological process whereby each generation constructs a conception of what is environmentally normal based on the natural world encountered in childhood (13). A problem arises insofar as the amount of environmental degradation increases across generations, but each generation tends to take that degraded condition as the nondegraded condition: the normal experience. This helps to explain inaction on environmental problems; people do not feel the urgency or magnitude of problems because the experiential baseline has shifted. Providing opportunities for people to experience more robust, healthy, and even wilder forms of nature in cities offers an important solution to this collective loss of memory and can counter the shifting baseline (14). Such opportunities include, for example, large green spaces and parks, rivers restored to some former free-flowing condition, expansive views over water and land, and extensive connective pathways for walking and biking.

Thus, cities designed well, with nature in mind and at hand, can be understood as natural, supportive of both ecosystem integrity and public health. Further psychological studies can describe how specific improvements in available opportunities for nature experience come to affect mental health and environmental attitudes (15). How will they change if car-clogged spaces give way to natural places where children can play wildly and others reflect quietly?

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## PERSPECTIVE

# Meta-principles for developing smart, sustainable, and healthy cities

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Policy directives in several nations are focusing on the development of smart cities, linking innovations in the data sciences with the goal of advancing human well-being and sustainability on a highly urbanized planet. To achieve this goal, smart initiatives must move beyond city-level data to a higher-order understanding of cities as transboundary, multisectoral, multiscale, social-ecological-infrastructure systems with diverse actors, priorities, and solutions. We identify five key dimensions of cities and present eight principles to focus attention on the systems-level decisions that society faces to transition toward a smart, sustainable, and healthy urban future.

By the year 2050, the number of people living in cities is expected to increase by about 2.5 billion (1). It is estimated that over 60% of the urban areas that will exist by 2050 have yet to be built, indicating that there will be massive new infrastructure requirements, particularly in Asia and Africa (2). Simultaneously, existing cities worldwide are aging and much in need of infrastructure replacement.

Infrastructures—defined broadly as the systems that provide water, energy, food, shelter, transportation and communication, waste management, and public spaces (3)—are essential to support human well-being and economic development. However, aggregated globally, these seven infrastructure sectors currently place a large burden on the environment and have a considerable impact on human health (Fig. 1). Urban demands dominate these effects; for example, ~70% of global greenhouse gas (GHG) emissions are attributable to cities (1). Because physical infrastructures have life spans of 30 to 50 years, the large imminent global requirement for new urban infrastructure presents a historic opportunity for change. The question is, how can urban infrastructure transformations in the 21st century advance the environmental sustainability and human well-being of our cities by taking advantage of the enormous potential offered by data science and technology?

Although information and communication technologies are important for developing smart, sustainable, healthy cities (4), we argue that a larger understanding of urban infrastructure systems is necessary to move from data to information to knowledge and, ultimately, to action for urban sustainability and human well-being.

With infrastructure as the focus, we identify five key dimensions of cities and present eight principles to help guide urban transformations toward sustainability and health, drawing on examples from the United States, China, and India.

## Key dimensions

Economic opportunity is a key driver for urbanization, and infrastructure is a prime enabler. Multi-city data sets are emerging that describe scaling relationships among urban population growth, gross domestic product (GDP), household incomes, and infrastructure-related parameters such as financial investments, energy and water use, and land and road expansions (5). Cities with different economic structures (e.g., highly industrial, highly commercial, or mixed economy) are known to exhibit different socio-spatial patterns of development (i.e., urban form) that affect infrastructure design. Yet basic city-level data on urban GDP, sectoral employment, and household incomes are sparse in many developing nations and in smaller cities and towns, where much urban growth is projected to occur.

Urban form or morphology describes the evolving interaction between physical space and human activity in cities. Numerous data sets, from census data to aerial and satellite photographs and remote sensing information, are being integrated to enable planners to characterize urban form. Urban complexity science is advancing new measures (4) that focus not only on population density, connectivity, proximity to jobs and services, and diversity and intensity of urban activities but also on understanding self-similarity across scales (from blocks to neighborhoods to cities) and patterns of social segregation (e.g., of migrant and informal populations in a city). Urban form represents the foundation upon which infrastructure develops, shaping energy and material use; access to and contiguity of water bodies, green space, and other critical ecosystems; and urban equity and well-being.

Infrastructure design and socio-spatial disparities within cities are emerging as critical determinants of human health and well-being.

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Editor's Summary

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