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Moving from features to functions: Bridging disciplinary understandings of urban environments to support healthy people and ecosystems

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ABSTRACT

Contact with nature can contribute to health and wellbeing, but knowledge gaps persist regarding the environmental characteristics that promote these benefits. Understanding and maximising these benefits is particularly important in urban areas, where opportunities for such contact is limited. At the same time, we are facing climate and ecological crises which require policy and practice to support ecosystem functioning. Policies are increasingly being oriented towards delivering benefits for people and nature simultaneously. However, different disciplinary understandings of environments and environmental quality present challenges to this agenda. This paper highlights key knowledge gaps concerning linkages between nature and health. It then describes two perspectives on environmental quality, based respectively in environmental sciences and social sciences. It argues that understanding the linkages between these perspectives is vital to enable urban environments to be

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planned, designed and managed for the benefit of both environmental functioning and human health. Finally, it identifies key challenges and priorities for integrating these different disciplinary perspectives.

1. Introduction

An extensive body of literature supports the idea that contact with nature can contribute to people's mental and physical health and wellbeing (e.g., Lovell et al., 2018; Twohig-Bennett and Jones, 2018).[1] Health and wellbeing benefits can be derived from the very presence of nature (e.g., trees and other green infrastructure can improve air quality (Escobedo et al., 2011) and mitigate noise pollution (Margaritis and Kang, 2017)), and also from the experience of sensory interaction with nature. Various typologies have been developed to differentiate the ways in which people interact with the natural environment for wellbeing benefit (e.g., Keniger et al., 2013; Marselle et al., 2021; Soga and Gaston, 2021), as well as the routes through which ecosystem functioning provides services (e.g., Díaz et al., 2018). Research and policy increasingly emphasise investigating the pathways through which benefits from nature are derived, with feelings of nature connectedness identified as a significant mechanism (e.g. Capaldi et al., 2014; Pritchard et al., 2019).

Understanding and maximising health and wellbeing benefits is especially important in urban areas, where over half of the world's population currently live (United Nations, 2019). Inequalities in health outcomes can be particularly stark in urban areas, and access to nature is often limited by the density of built development, especially in more socio-economically deprived areas (Schwarz et al., 2015). This can lead to physical, physiological, and psychological disconnection from nature (Soga and Gaston, 2016), particularly amongst people who experience socio-economic disadvantages (Schüle et al., 2019). Evidence suggests that the health benefits of nature are greatest for those of lower socio-economic position (Mitchell and Popham, 2008; Rigolon et al., 2021), suggesting that interventions aimed at improving access to environments can narrow social inequalities.

At the same time, we are facing climate and ecological emergencies (Cottey, 2022). Anthropogenic disruptions of natural systems are leading to breaches of the "safe operating space for humanity" (Richardson et al., 2023: 1). Urban environments face disproportionate negative impacts on human populations (Gasper et al., 2011). This necessitates urgent action to support the functioning of natural systems and prevent their destruction to support human health. Governments and public bodies often advocate holistic approaches to planning, designing and managing "good quality green infrastructure" to "deliver multiple benefits for people and nature" (Natural England, 2023: unpaginated), especially in the global North (Pauleit et al., 2021). However, knowledge gaps remain regarding how the environment (both in terms of presence and quality of environmental characteristics) produces health and wellbeing benefits, how benefits may vary between people and contexts, and the causal pathways that link environment features and quality to human health (Beute et al., 2020).

In 2021, the UK Natural Environment Research Council funded a project to develop an interdisciplinary, multi-sector network of academics and practitioners to investigate the links between "the Quality of Urban Environments, Nature Connectedness and Health" (QUENCH, 2022). This paper developed from conversations within that network. Discussions revealed that it was imperative that if we are to successfully address the diverse challenges in research and policy relating to the links between nature and health, then we needed to bring together the different perspectives on nature and health in the social, health and natural sciences in new ways. In this paper, we propose a new conceptual framework that facilitates engaging with these different perspectives together, to effectively respond to environmental and population health and wellbeing challenges. Specifically, we argue for the need to explore the linkages between environmental functioning, experience of environment (and in particular feelings of nature connectedness), and health outcomes. We present an illustrative diagram summarising this conceptual framework in Fig. 1, which we expand on in subsequent sections.

We first highlight the rationale for researching the linkages between engaging with nature and health outcomes. We then describe environment-oriented and people-oriented perspectives on environment and environmental quality. Next, we argue that understanding the linkages between these perspectives is vital to enable urban environments to be planned, designed and managed for the benefit of both environmental functioning and human health. Finally, we identify key challenges and priorities for integrating these different disciplinary perspectives.

2. Rationale

Recently developed models and frameworks, key characteristics of which are summarised in Table 1, offer conceptual guidance for addressing knowledge gaps in this area. These papers have helped establish a research agenda to understand the pathways between environmental features (variously conceptualised according to the needs and aims of each framework) and health. Here we go beyond these existing frameworks to emphasise a need to conceptualise the environment as a functioning biophysical system rather than as a set of perceivable components or features, and for this functioning system to be considered as the starting point for the identification of causal pathways. In doing so, we seek to further advance the call for a more detailed specification of how studies integrate and measure the characteristics and qualities of the environment (Hunter and Luck, 2015; Bratman et al., 2019; Marselle et al., 2021). Building on several of these frameworks (Bratman et al., 2019; Gaston et al., 2018; Hartig et al., 2014; Marselle et al., 2021), we seek to further refine here the differentiation between the environment and the experience of environment, by drawing attention to pathways between urban nature and health outcomes that are a) independent from and b) dependent upon experience, with nature connectedness as a key mediating factor for the latter. These developments will better enable researchers, policymakers, and practitioners to identify interventions to generate benefits for human health and nature simultaneously.

While linkages between engagement with nature and health/wellbeing benefits have been extensively considered (e.g., Hartig et al., 2014; Lovell et al., 2018; Richardson and Hamlin, 2021; Twohig-Bennett and Jones, 2018; White et al., 2021), particularly in the global North, questions about the specific environmental functioning that underpin these benefits remain under-researched. A large body of research links environmental science to mental health research, but the direct contribution of environmental science tends to be limited (Roberts et al., 2023). While measures of quantity and density of, proximity to, or time spent in green space are common, many studies treat such spaces as broadly undifferentiated and ignore their overall functioning (Collins et al., 2020; Evans et al., 2022). Where green spaces are differentiated, studies often provide little detail about specific processes, such as species richness, type of habitat, or the integrity of nutrient cycling or water infiltration (Hunter and Luck, 2015; Taylor and Hochuli, 2017), or fail to compare between them (Beute et al., 2023).

Where research on nature-health linkages has investigated

[1] By "nature" and "environment" we mean "areas containing elements of living systems that include plants and nonhuman animals across a range of scales and degrees of human management" (Bratman et al., 2012: 120), which are constituted by both biotic and abiotic elements.

environmental quality, studies have almost exclusively focused on biodiversity or type of vegetation, rather than on environmental functioning (e.g., Cox et al., 2017; Dallimer et al., 2012; Fisher et al., 2023; Fuller et al., 2007; Hepburn et al., 2021; Hoyle et al., 2019; Irvine et al., 2023; Knight et al., 2022; Marselle et al., 2013; Southon et al., 2018; Wood et al., 2018). The first systematic review of studies investigating health and wellbeing benefits from contact with biodiversity found that many included proxies and perceptions as indicators, i.e. did not necessarily involve field-based ecological assessment of biodiversity (Lovell et al., 2014). An update to this review, focused on mental health and wellbeing, found a substantial increase in the number of studies utilising various different measures of actual biodiversity, providing some evidence that biodiversity promotes better mental health and wellbeing. However, with many studies reporting non-significant results, albeit due to a range of possible limitations, it concluded that there was insufficient evidence to characterise the role of biodiversity in relation to mental health or wellbeing (Marselle et al., 2019).

While there is an overabundance of associational-based evidence linking nature and health, we need greater investigation of the causal pathways that have been proposed, moving beyond correlative study designs (Roberts et al., 2023; Sandifer et al., 2015). Proposed conceptual pathways do exist for some (e.g., explaining the associations between green space and wellbeing), but not all aspects of environments (Schwarz et al., 2017). Most theoretical frameworks do not link their explanations back to environmental functioning of the whole environment system, rather linking them to components, features or categorisations of those systems.

We also underline a further knowledge gap, specifically the relationship between environmental functioning and nature connectedness. We define nature connectedness as an individual's psychological relationship with nature, focused on affective, emotional and experiential interactions with nature as part of an individual's experiences or identity (Mayer and Frantz, 2004). It has been argued that connection with nature is a basic human psychological need (Baxter and Pelletier, 2019), and a growing body of evidence suggests that many health benefits derived from nature are mediated through nature connectedness (e.g., Capaldi et al., 2014; Liu et al., 2022; Pritchard et al., 2019). Higher levels of nature connectedness have also been associated with pro-environmental attitudes and behaviours (Martin et al., 2020; Mayer and Frantz, 2004; Richardson et al., 2020). Physical and psychological disconnection from nature discourages positive emotions, attitudes and behaviours towards the environment (Soga and Gaston, 2016). Simultaneously, people's thresholds for acceptable environmental conditions (e.g., extent and composition of wildlife populations) are continually being lowered (Soga and Gaston, 2018). Reconnecting people with nature is thus of vital importance both for human health and wellbeing, and to make the social, political, and economic changes necessary to tackle the climate and ecological crises. Although pathways to enhancing people's sense of nature connectedness have been proposed (Lumber et al., 2017), these relate to the individual's *experience* of nature, and there is considerably less understanding of the ways in which 'environment-oriented' features or qualities might affect experiences of nature and nature connectedness (Lengieza and Swim, 2021).

Urban ecosystems present a critical and challenging research frontier. Understanding urban ecosystem functioning presents major challenges, e.g., due to the many introduced species, complex and fragmented spatial distributions, highly modified biogeochemical flows, and elevated presence and novel combinations of pollutants in such systems (Grimm et al., 2008). Urban areas play an important role as drivers of nature loss and poorer environmental functioning (through pollution, land use change, resource use, etc.). However, through implementing nature-based solutions, they can also play a key role in enhancing biodiversity, environmental functioning, access to nature, nature connectedness and pro-environmental behaviours (Oke et al., 2021; Samus et al., 2022). Addressing this complexity and developing a better understanding of the linkages between environmental functioning (including both presence of features and quality), environmental experience, and human health, is vital to inform policy and practice around the provision, design, and management of urban nature. This has become increasingly important since the Covid-19 pandemic which highlighted the impact of inequalities in access to good quality nature in urban areas (O'Brien et al., 2023; Shoari et al., 2020).

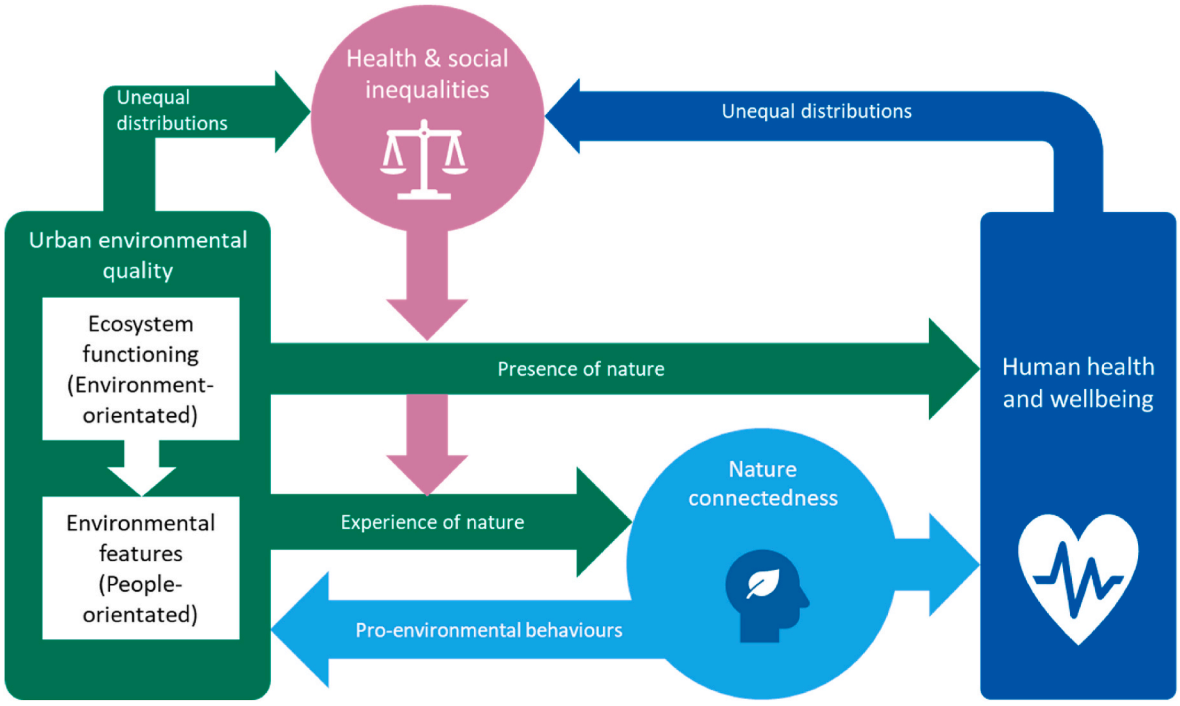

Fig. 1. Illustration of the connections between urban environmental quality and human health and wellbeing, and the need for interdisciplinary research that spans environment-oriented and people-oriented approaches. Arrows show indicative and selected connections only for simplicity.

3. Two complementary perspectives on thinking about the environment

3.1. Environment-oriented perspective

The environment-oriented perspective is primarily concerned with the functioning of environmental processes which underpin our economy, society, and very existence. This perspective is based in environmental sciences such as ecology, atmospheric sciences, environmental chemistry, soil science, and hydrology. It considers the environment to be a set of interconnected physical, chemical and biological processes and functions: biotic and abiotic elements that are linked through cycles and flows of matter and energy (Manning et al., 2018). These elements include flora, fauna, and the soil, water, and air compartments. The flows which link them and constitute environmental functioning include carbon and nutrient cycling and the hydrological cycle. These flows are embodied in processes such as biomass production (plants photosynthesizing and growing), decomposition (the breakdown of organic material), and food webs (in which some members of a biotic community feed or consume others). From this perspective, urban environments exist independently of the perceptions and experiences of people in those places.

This perspective may describe the environment by a wide array of features, processes and qualities, including (but not limited to).

- Ecosystem integrity: an ecosystem's capacity to maintain its structure and functions using processes and elements characteristic for its location (Dorren et al., 2004)
- Ecosystem health: a state of system organization, resilience, and vigour, as well as the absence of signs of degradation and distress (Rapport et al., 1998)
- Soil health: the capacity of soil to function as a living ecosystem, assessed by its biological, chemical, and physical composition (Lehmann et al., 2020)
- Water quality: the extent to which water meets standards required for particular functions - e.g., supporting aquatic life, safety for human contact - assessed by its biological, chemical, and physical composition (Uddin et al., 2021)
- Air quality: the extent to which air meets standards required for particular functions – e.g., avoidance of acidification, safety for human breathing – assessed by concentrations of solid particles and chemical pollutants (Manisalidis et al., 2020)

The focus for this perspective is the *functioning* of whole environmental systems, rather than the state of individual features of environments or specific qualities (Leuzinger and Rewald, 2021). For example, the idea of soil being assessed in terms of 'health' is intended to convey the sense of soil as a dynamic, constantly changing system, as opposed to a static or inert growing medium (Wood et al., 2017). What makes a soil healthy (e.g., in terms of its structure, chemistry, biology, organic matter content, and water infiltration and retention properties) is its capacity to perform a range of *functions* – particularly carbon, nutrient, and water cycling, and supporting biodiversity – appropriate to its context. This environment-oriented perspective is largely absent from research on the linkages between engagement with nature and health outcomes.

3.2. People-oriented perspective

From the perspective of human and social sciences (e.g., psychology, health and medical research, sociology, human geography, anthropology, and public health decision-making), the environment is understood as what surrounds people: it is a venue for experience and social action (Castree et al., 2014: 765). Nature holds a wide diversity of values for people, developed through socially, culturally and historically specific ways of understanding and connecting with it, many of which are marginalised in policymaking and need to be better acknowledged, understood, and integrated (IPBES, 2022).The important and relevant characteristics of the environment from this perspective are those that people can engage with through their senses and/or interactions (Gaston et al., 2018). Rather than environmental processes occurring more-or-less independently from experiencing humans, these characteristics are co-produced through the sensory, perceptual, and experiential interaction between humans and the environment, including feelings of nature connectedness.

Environments may be conceptualised from a people-oriented perspective to include factors such as perceptions of naturalness, colour, wildness, species richness, safety, sense of place, tranquillity and beauty. It may draw on sensory perceptions of sight, smell, taste, touch, and sound, as well as more complex cognitive and affective constructs such as 'atmospheres' (Sumartojo and Pink, 2018). For example, Annerstedt et al. (2012) characterised the variable qualities of environments relevant to health benefits as serene, wild, lush, spacious, and cultural, all of which combined environmental elements (e.g., species richness, type of land, water and/or vegetation cover) with perceptual elements (e.g., feelings of restfulness, peace, coherence).

Table 1
Key characteristics of proposed models and frameworks linking nature and health.

Authors	Purpose	Proposed framework/model	Characterisation of nature/environment	Aspect of health
Hartig et al. (2014)	Organise existing research on pathways between nature and health; set out research priorities and challenges	Model linking contact with nature to health via four interacting pathways: air quality, physical activity, social cohesion, stress reduction	Physical features and processes of nonhuman origin that people ordinarily can perceive	Mental, physical and social health
Hunter and Luck (2015)	Improve understanding of how specific qualities of urban green spaces influence the generation of social-ecological value (e.g. health benefits)	Typology of 14 qualities (person-oriented and environment-oriented) that can define green space type, and help identify pathways by which environments yield social-ecological value	Biotic and abiotic elements alongside social elements such as access, physical features (benches etc), management, etc	Mental and physical health
Markevych et al. (2017)	Improve understanding of biopsychosocial pathways linking green space to health benefits	Framework linking green space to human health via three pathways: reducing harm, restoring capacities, and building capacities	Generic category of "greenspace"	Mental, physical and social health
Gaston et al. (2018)	Improve understanding of how people experience nature and what components of nature they experience	Framework characterising person-nature interactions at individual, population, and multiple population levels, from both person-oriented and environment-oriented perspectives	Living things, ranging from individual organisms to ecosystems	Mental, physical and social health
Bratman et al. (2019)	Help to make predictions regarding the average, population-level impacts of environmental change on mental health	Model linking nature and mental health by sequentially characterising specific natural features, exposure to those features, experience of those features, and health effects of that experience	Specific natural features, including size, type, composition, spatial configuration, and biodiversity	Mental health
Marselle et al. (2021)	Develop a better understanding of the pathways through which biodiversity can influence human health	Framework linking exposure to and experience of biodiversity to human health via four potentially interacting pathways: reducing harm, restoring capacities, building capacities, causing harm	Composition, configuration, and diversity of species or habitats; abundance, biomass, functional traits, and genetic composition of species	Mental, physical and social health

People-oriented perspectives on environments are subject to a wide range of psychological, cultural, and social influences, including individual-level factors such as knowledge, gender, age, preferences, skills, and cultural background. Understandings of and cognitive and emotional responses to environmental features or qualities are also dynamic and change over time. In many studies where 'people-oriented' environmental features or qualities have been assessed, factors that are not directly associated with environmental functioning are frequently included, e.g., access, ownership, recreational use (Hunter and Luck, 2015), or the presence of features such as paths, playgrounds, lighting, toilets, litter, and graffiti (Wood et al., 2018). While potentially (but not necessarily) linked to environmental functioning in beneficial or harmful ways, these factors are important to the human experience of the environment in terms of, e.g., sense of comfort, enjoyment, and belonging. Alongside nature-based programmes such as parkruns, green social prescribing and green gyms, they can influence motivation to visit and spend time in urban nature.

4. Bringing the perspectives together

Research and action into the environment- and people-oriented perspectives often treat them in silos or utilise simplistic interactions. Here we argue that we need to move towards studying them both as whole interconnected systems if we are to advance the field.

4.1. Human health and environmental functioning

Both the environment-oriented and person-oriented perspectives offer valid and important ways of interpreting urban environments. Considering both together, and better understanding their interactions, is essential to achieve holistic approaches to generating benefits for people and nature, such as nature-based solutions (Liu et al., 2021; UNEP, 2022) and the Nature Futures Framework (Pereira et al., 2020). Working with both perspectives will enable better understanding of how these multiple benefits can be 'stacked' within the context of multiple demands and socio-economic constraints on provision of green and blue space.

Integrating these perspectives requires the creation of opportunities for environmental, social and health scientists, together with practitioners and policymakers, to come together to explore these issues, building, for example, on the network and proof-of-concept studies developed through the QUENCH programme (QUENCH, 2022). Crucially, this must be achieved through genuinely interdisciplinary approaches respecting both perspectives, rather than attempting to reduce one to the other or interpret one in the terms of the other.

Thinking in terms of the people-oriented perspective is necessary at the most basic level because if people do not perceive urban environments as safe or attractive then they will not choose to spend time in them. These perceptions may vary by social factors such as gender, ethnicity, (dis)ability, socio-economic deprivation, and age (Barker et al., 2022; Collier, 2020; O'Brien et al., Undated; Williams et al., 2020), and will furthermore affect individuals' feelings of nature connectedness. A better understanding of how the people-oriented perspective, and human health outcomes, relate to the environment-oriented perspective is necessary. Spaces that are designed and managed based only on a people-oriented perspective of environments may be unsustainable in the long term (van Heezik and Brymer, 2018), and may not contribute as much as they could to environmental targets such as nature recovery and/or ecosystem service provision. Functioning ecosystems provide a wide range of services that are not obviously related to human perceptions of environmental quality, some of which may have considerable direct or indirect human health impacts (Andersson et al., 2015; Chen et al., 2019). Processes that are vital to ecosystem functioning may also impact negatively on human health, e.g., the spread of allergenic pollen (von Döhren and Haase, 2015). While there is a substantial body of research on the linkages between experience of environment and health outcomes, the effects of environmental functioning on these linkages is under-researched.

4.2. Key challenges and priorities

Here we outline the key research areas that we argue need to happen to realise our vision.

***Moving beyond features to functions*:** There is a relatively established literature linking biodiversity with wellbeing (Lovell et al., 2014; Marselle et al., 2019). More recently, studies have investigated the links between other environmental characteristics and wellbeing. Examples include Hoyle et al. (2019) who assessed the experience of nature in relation to characteristics of vegetation type, structure, and density, and Beute et al. (2023) who systematically reviewed studies exploring the types and characteristics of urban green spaces which impact on mental health and wellbeing. Important as these developments are, they continue to focus on the *features* rather than the *functioning* of environments, and only in some cases additionally engage a person-oriented perspective.

The relationship between perceivable environmental features and underpinning environmental functions can be thought of in terms of the English language metaphor "the tip of the iceberg", where the (visible) tip of the iceberg represents a small, known part of something much larger and unknown, represented by the submerged majority of the iceberg. Environmental functions – biogeochemical flows, ecological processes etc. – are at most only partially perceivable in the environment-as-experienced. However, many features that people do engage with, and which form the perceivable tip of the 'environmental quality iceberg', are a result of these unseen functions and processes. The challenge is to relate these 'invisible' processes to health, exploring the linkages between the seen and the unseen and tracing the pathways from environmental functioning to health outcomes, both directly and through experience of environment and nature connectedness. A highly-simplified schematic example of such pathways is shown in Fig. 2.

Understanding complexities: The pathways linking the different aspects of environmental features, qualities and functioning are unlikely to be consistent across different health outcomes. Physical health itself incorporates different bodily systems that are each affected by different stressors. Mental health and wellbeing are also similarly diverse (e.g., affective vs cognitive). These outcomes and their environmental influences are likely to be different in the short- and longer-term. Positioning nature connectedness as a mediator of these mechanisms further adds complexity to explaining these processes. We need to embrace this complexity, avoiding generalising environment benefits on health as consistent, in how we design studies if we are to understand the holistic benefits of environments.

Synergies, divergence, and trade-offs: Whilst planning and managing urban environments to benefit both the environment and human health can be complementary, in some cases these purposes may conflict with or simply diverge from each other. For example, an intuitive assumption is often made that more biodiverse environments are likely to promote greater nature connectedness and health benefits. However, studies that have empirically tested this assumption have found mixed results. Some studies have found that higher levels of biodiversity generate greater health and wellbeing benefits (e.g., Southon et al., 2018; McEwan et al., 2019; Young et al., 2020), but others have found that health benefits correlate with perceived rather than actual biodiversity levels, and that these perceptions are often inaccurate (e.g., Dallimer et al., 2012; Schebella et al., 2019). To enable informed decisions, maximise synergies, manage conflicts, and negotiate trade-offs between these two vital agendas, a more detailed understanding of the relationships between the two is required. For example, despite increasing movements to make urban nature more biodiverse and multifunctional, especially in the global North, the majority of urban green spaces still tend to be managed with a focus on neatness, e.g., mown monoculture lawns for recreation, and a low tolerance for

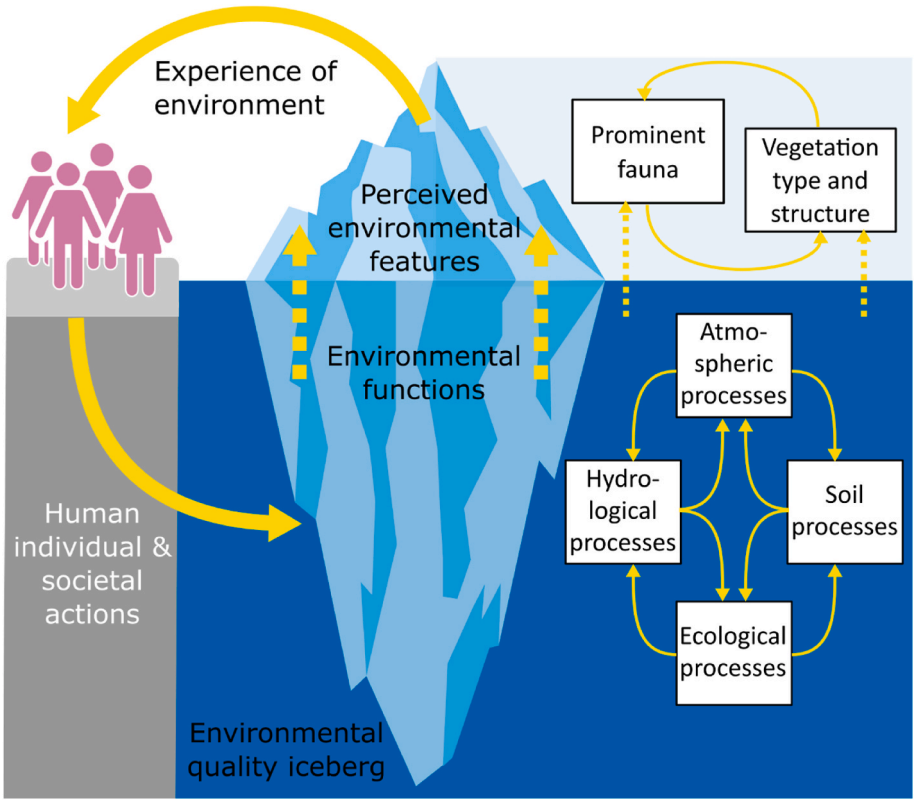

Fig. 2. The environmental quality iceberg. Environmental quality is made up of both seen and unseen features. The largely 'unseen' elements of the environment – the environmental functions – lie below the perceived features of the environment. The interconnected processes that occur in the atmosphere, soils etc. that make-up environmental functioning give rise to features that are more readily perceived, such as vegetation type and prominent fauna. These perceived features are experienced by humans, who in turn, through individual and societal actions change the both the 'seen' and 'unseen' aspects of environmental quality.

biological 'mess' such as 'weeds', dead leaves, and long grass, which contribute to environmental functioning (Ignatieva et al., 2020). There is evidence that publics increasingly prefer, and local governments are increasingly willing to provide, more diverse urban nature (Fischer et al., 2020; Hoyle et al., 2017). However, this comes in a context where "the lawn has been an unquestioned norm and people perceive lawns as urban nature" (Ignatieva and Hedblom, 2018), with social, political, economic, and cultural barriers to change. Likewise, less managed ecosystems that may have high value from a functional, environment-oriented perspective (such as scrubland or salt marshes) may be perceived as lower quality from a people-oriented perspective and inspire lower levels of nature connectedness in some individuals, e.g., if they do not fit with conventional imaginaries for aesthetic beauty or recreation, and may also be perceived as less well cared for (Denyer, 2013).

We need to identify situations in which interventions in urban ecosystems intended to deliver health benefits and enhance nature connectedness could undermine environmental functioning, and vice versa. A better understanding of the pathways between environmental functioning, nature connectedness and human health is vital to avoid such divergences where possible, maximise synergies by prioritising actions that benefit both human health and environmental functioning, and inform decision-making on trade-offs where necessary. It may also be possible to inform strategies to mitigate against the impacts of such trade-offs, e.g., using insights from the people-oriented perspective about what people value to mediate or moderate potential negative responses to interventions designed to improve environmental functioning (which may e.g., exclude people from places, restrict their activities within them, or change them in other ways that are perceived as unwelcome).

Exploring diversity and inequalities: The same environment can produce markedly different experiences across different individuals and social groups. Individual experiences of nature combine the environment with a broad range of social, cultural, and demographic factors, along with individual life histories, physical capacities, and preferences (Beery et al., 2023). Within this complex assemblage, nature connectedness is a highly individual characteristic. People will thus experience nature very differently, and this experience will have significant consequences for feelings of nature connectedness and resulting health outcomes. Differences in, or changes to, the features, qualities or functions of an environment that may enhance nature connectedness for one person may diminish it for another.

More evidence is needed on the forms of urban environment that may be beneficial for each diverse community within urban populations, and on the functions which underpin and link them. This needs to be considered in the context of existing health and environmental inequalities, and differing perceptions of and access to urban nature (Ward et al., 2023). Research, policy, and planning should systematically engage vulnerable and marginalised groups who are currently less likely to access urban nature, such as people with lower incomes, lower educational attainment, those not in work, women, teenagers, and minoritised ethnic groups (Cronin-de-Chavez et al., 2019; Holland, 2021). There is also a need for more research where less is known about the experience of nature by specific social groups (Bell, 2019; Birch et al., 2020), and on intersectional categories, e.g., older women from minoritised ethnic groups. The geographical spread of research in this space needs to be extended, as it cannot be assumed that research findings from urban areas in the global North (accounting for most research in this space) are readily translatable elsewhere.

Temporalities: The timescales of experience of nature from a people-oriented perspective, and the timescales of environmental functioning from an environment-oriented perspective, do not necessarily coincide.

Factors such as weather, time of day, and season have significant influence over, for example, which species might be active or visible in particular environments, how lush vegetation might appear, and how likely watercourses are to appear depleted or flooded. While discharges of raw sewage into rivers may be recognisable in the short term, bacteria, viruses, parasites, and excess nutrients carried by such discharges may remain after the visible signs of pollution have passed (Xie et al., 2022). Fertilizers applied to soils can reside in the subsurface for timescales varying from minutes to centuries, meaning that disturbances to nitrogen and phosphorus cycles may take decades to rebalance (Van Meter et al., 2016), even though their impacts on ecosystem functioning are only intermittently perceptible to non-experts. Pesticides such as neonicotinoids can accumulate in plants, soils, and waters long after their application (Alsafran et al., 2022). Many changes to ecosystem functioning due to climate change are already locked in by the historical emission of greenhouse gases but are not yet perceptible (Fankhauser, 2017). Human viewpoints and perceptions are typically immediate, facilitating engagement with features and impeding engagement with processes. There is a need to explore the relationships and disjunctions between the temporalities of environmental experiences and environmental functioning.

Feedback loops: Investigating the linkages between human health, the experience of environment (especially the sense of nature connectedness), and environmental functioning opens possibilities for cultivating positive feedback loops between the objectives of improved human health and improved environmental functioning. Higher levels of nature connectedness are a predictor of pro-environmental and pro-conservation behaviours and attitudes (Martin et al., 2020; Richardson et al., 2020). A better understanding of the linkages between environmental functioning and nature connectedness could provide important evidence to inform the design, planning, and management of urban environments in ways that directly benefit the environment as well as human wellbeing, while also cultivating nature-positive intentions and actions.

Making the most of existing data to assess impacts on human health: Various data sources can be used to understand both physical and mental health including physiological markers (e.g., blood pressure), social determinants of health (e.g., educational attainment, income), and prevalence rates of long-term health conditions, as well as proxies for prevalence (e.g., prescribing patterns). Of particular interest are modifiable risk factors, such as physical inactivity or high blood pressure, which are both significant risk factors for cardiovascular disease and Type 2 diabetes. Routinely collected data offer value to answering research questions, but tend to be used less frequently than surveys or interviews. Recent examples of this approach include utilising household-level longitudinal environmental metrics (access to green and blue space and enhanced vegetation index) linked to longitudinal electronic health records (Geary et al., 2023; Thompson et al., 2022), and using a suite of longitudinal quantitative data from established cohorts to understand how the built environment influenced children's modifiable risk factors for non-communicable diseases (Pedrick-Case et al., 2022).

Data from bodies such as health services, schools, and local authorities, whilst sometimes difficult to access, can cover a broader range of individuals than those willing and able to fill out surveys. The value of these data is increasingly recognised - e.g., in the UK organisations such as Administrative Data Research UK, Health Data Research UK, UK Longitudinal Linkage Collaboration, and the ONS aspire to make data linked and available for research nationally. Privacy can be protected and access made easier by study design that includes use of aggregated data where possible; although such data may not be able to be used to infer causality, it remains powerful when used appropriately. There is a wide range of questions that routinely collected data could be used to help investigate, such as the relationships between health inequalities and different types and qualities of urban nature - although there is also a need for much better long-term, real-time data on urban nature (Wägele et al., 2022). Another form of increasingly abundant health data is available through personal devices such as mobile phones and smart watches. Although data source-specific matters (e.g., bias of ownership and use of such devices, accuracy of data) require consideration, this represents a potentially highly valuable source of individual and aggregate health data that could be associated with geospatial data on types, quantities, qualities, and characteristics of urban nature in the areas where they are used.

Methodologies: Most research in this space to date has been cross-sectional, examining exposure to nature (often focused on actual or potential access or proximity to green space) and health outcomes at the same time (Hartig et al., 2014; Markevych et al., 2017). These approaches need to be expanded with a range of additional methodologies for developing understandings of the links between environmental functioning, the experience of environment, and health outcomes (Chen et al., 2019). Longitudinal studies such as cohort studies and household panels, in which people are followed over time with repeated monitoring of health outcomes and other variables of interest (e.g., nature connectedness and engagement with particular environments) can provide rich, detailed data on how people interact with environments and health outcomes, helping to establish causal pathways and mechanisms, contextualised within individual biographies. However, there remain methodological challenges (e.g., relating to multiple interacting factors of interest) when using routinely collected health and socio-economic data alongside environmental and planning data. Multiple cohorts can be pooled using linked cohort data, which retains some data richness and enables increased numbers to be studied. Record-linkage studies accessing spatially-organised, routinely collected health data (discussed above) can be cross-referenced with existing or newly-mapped or modelled area-specific environmental data, e.g., ecological function analysis (Brodie et al., 2018) or assessment of the resilience of ecosystem functions (Oliver et al., 2015).

Natural experiments (where planned changes are made to the environmental characteristics of an area, e.g., through habitat creation or flood alleviation schemes) should be utilised as opportunities to take measurements before and for several years after interventions, ideally with no-change control sites for comparison. Novel interdisciplinary approaches will be needed to drive this research agenda in response to the irreducible complexity of the issues at stake when both perspectives on environmental quality are held in view (Donaldson et al., 2010). Experimenting with interdisciplinary mixed methods approaches has the potential to produce new, deeper, and more nuanced understandings of human-environment relations and interactions (Brockett et al., 2019). Information on how the QUENCH proof-of-concept studies have contributed to this experimentation, e.g., by encouraging interdisciplinary collaboration and approaches alongside novel methods to integrate people-oriented and environment-oriented perspectives can be found in the projects, resources and events sections of the QUENCH website (QUENCH, 2022).

5. Conclusion

We have argued that we need to integrate environment-oriented and people-oriented perspectives on environmental characteristics and qualities, and shift from a focus on environmental features to environmental functions, if environmental management and design – in particular for urban nature – are to have positive outcomes for both human health and environmental functioning. To drive a research agenda to provide the evidence needed to underpin this, we make the following summary recommendations.

- Extend the focus of research on the health outcomes of engaging with nature from environmental features to environmental functioning
- Experiment with interdisciplinary mixed methods to better understand the linkages between the functioning of environments from an environment-oriented perspective, the experience of environments

from a people-oriented perspective with a focus on nature connectedness, and subsequent health and wellbeing outcomes
- Focus on identifying synergies and conflicts between interventions to promote human health, nature connectedness and environmental functioning
- Explore the effects of social, cultural, and demographic diversity and inequality on health outcomes from engaging with nature
- Explore the differing temporalities of engagement with nature and environmental functioning
- Further explore potential feedback loops between healthily functioning ecosystems, nature connectedness, health outcomes, and pro-environmental attitudes and behaviours
- Extend the range of methodologies used to assess human health in research on nature and health
- Focus on longer-term research that can explore change over time in communities and the nature that surrounds them.

CRediT authorship contribution statement

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No data was used for the research described in the article.

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