

Nature Connection: Providing a Pathway from Personal to Planetary Health

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Abstract: The vast and growing challenges for human health and all life on Earth require urgent and deep structural changes to the way in which we live. Broken relationships with nature are at the core of both the modern health crisis and the erosion of planetary health. A declining connection to nature has been implicated in the exploitative attitudes that underpin the degradation of both physical and social environments and almost all aspects of personal physical, mental, and spiritual health. It is increasingly clear that the entwined challenges of biodiversity loss, climate change, and human health cannot be addressed without addressing selfishness, greed, apathy, and the value systems that created these global problems. Calls for a spiritual and cultural transformation recognize that “inner” development is important and necessary for meaningful “outward” transitions with a shared purpose for wiser, more sustainable societies. Many of these emotional and spiritual assets appear to be facilitated by a connection to nature, which is also strongly associated with community cohesion, prosocial attitudes, and pro-environmental actions. Restoring the human connection to nature may therefore provide a critical common pathway to promote the physical and spiritual wellbeing of individuals and communities as well as personal and social environmental responsibility. In this paper, we summarize and reflect on the discussions of the Nova Network planetary health community with respect to nature-based solutions as pathways to promote both personal and planetary health with a more mutualistic mindset. These discussions spanned biological to psychological interactions with nature—including the critical relationships with environmental microbes that influence the physical, emotional, and behavioral aspects of health. We consider the ways in which stronger relationships with nature promote “inner assets” to support “outward actions” for personal and planetary health.

Keywords: nature relatedness; pro-environmental attitudes; biodiversity; microbiomes; personal health; planetary health; altruism; inner development; spirituality; value systems



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1. Introduction

The Anthropocene has been characterized by a disconnection from nature as humans have turned away from traditional ways of living in harmony with the natural world and have adopted increasingly extractive and exploitative relationships with the environment (Figure 1) [1,2]. The declining value of nature has been implicated in the degradation of both physical and social environments and almost all aspects of human health. The loss of natural habitats and biodiversity (including microbial ecosystems [3]) and the pollution of the air, water, and soil as a consequence of human actions impact the wellbeing of life on our planet, including our own [1,4].



Figure 1. Mindsets of the Anthropocene: Extractive, exploitative attitudes toward nature have accelerated since the industrial revolution, fueled by hedonistic self-interest, greed, and consumerism. Ideologies of unchecked “economic” growth have dominated and displaced deeper intentional wisdom such as Indigenous traditions, which recognize the vital reciprocity and balance of nature (art created by author S.L.P.).

Broken relationships with nature are also reflected in a mounting spiritual crisis [5]—the erosion of deeper meaning and shared purpose, mental anguish, fear, polarization, distrust, despair, and surging violence—leading to widespread social breakdown [6]. As community cohesion declines, people are less likely to engage in activities and practices that promote a sense of connection, purpose, and belonging [7–11]. With growing pessimism and cynicism, people are less likely to care about the environment and are less likely to engage in actions to protect it [11]. This underscores the importance of restoring optimism as a powerful motivator for social cohesion and engagement towards environmental solutions [12,13]. Moreover, shared positivity (i.e., resonant purpose with others) makes life more meaningful [14].

Promoting human health and the flourishing of all life on Earth requires urgent, deep, structural changes to the way in which we live [15]. This must include our value systems, belief systems, and other aspects of human consciousness required to advance the Sustainable Development Goals (SDGs) [16] and improve planetary health [17]. Development efforts should therefore emphasize the importance of spirituality, creativity, self-awareness, and other character strengths needed for consciousness-driven transformations. These positive assets not only benefit individuals [18,19] but also lead to more cohesive communities, wiser societies [20] with less polarization [21], and a stronger sustainability culture [19,22–25]. In other words, “inner” transformations are important for shared “outward” transformation [22].

This has led to initiatives such as the Inner Development Goals (IDGs), which aim to accelerate progress towards the SDG through greater investment in emotional intelligence, connectedness, and caring for others and the natural world [26]. Many of these emotional and spiritual assets and personal growth appear to be facilitated by a connection to nature [27–30], which also strongly promotes pro-environmental actions [31–33].

Restoring human connections to nature may therefore provide a critical common pathway to mitigate adversity and promote the physical [34–37] and spiritual well-being of individuals [30,35,38,39] and communities [40,41], as well as personal and collective social and environmental responsibility [42–44].

In this paper, we synthesize, summarize, and reflect on the proceedings of the Nova Network Planetary Health discussions (held virtually in 2021–2022), which considered a connection to nature as a pathway to promoting both personal and planetary health with a more mutualistic mindset. These discussions spanned biological to psychological interactions with nature—including the critical relationships with environmental microbes that influence the physical, emotional, and behavioral aspects of health. We also considered how stronger relationships with nature promote the “inner assets” and attitudes for “outward actions” towards social cohesion and environmental responsibility to mitigate the personal and planetary health crises.

“I used to think the top global environmental problems were biodiversity loss, ecosystem collapse and climate change. I thought that with 30 years of good science we could address these problems. But I was wrong. The top environmental problems are selfishness, greed and apathy, and to deal with these we need a spiritual and cultural transformation, and we scientists don’t know how to do that.” James Gustave Speth [45]

2. Rediscovering What We Have Lost: (Re)learning from Indigenous Knowledges

These concepts are not new. Indigenous traditional knowledges have long recognized the vital balance and sacred reciprocity of natural systems and rhythms—a perspective that encompasses the living energy of nature with spiritual rather than just materialistic value [46]. The “bonds between humans, spirit and nature” and the interconnectedness of all life [47] are foundational within many Indigenous, land-based worldviews [48]. These perspectives and practices can be of enormous value in influencing Western value systems toward more sustainable worldviews.

For many Indigenous cultures, the concept of “environmental responsibility” is not a separate issue from other aspects of life. Instead, it is seen as an integral part of living in harmony with the natural world and upholding cultural values and responsibilities. This may involve taking care of the land and resources in a way that ensures sustainability for future generations, respecting the rights and needs of other beings in the natural world, and a deep sense of spiritual connection to all things [47,48].

This relational worldview is at odds with the primarily individualistic and “transactional” nature of modern Western culture. The deep and intentional reciprocal relationships of Indigenous peoples with nature have been undervalued and even undermined by most modern societies, with many Indigenous communities suffering disproportionately from Western cultural changes [48,49].

However, there is a growing recognition that Indigenous perspectives may provide valuable knowledge and wisdom and an imperative for applying more long-range, integrated thinking [48]. As Western cultures grapple with the consequences of a planetary-scale environmental crisis and a mounting spiritual crisis, these more nature-centered, spiritual perspectives play an increasing role in promoting the planetary health agenda [46,48]. Indigenous perspectives also assist in overcoming siloed, reductionist thinking that compartmentalizes the many complex challenges experienced by modern societies by providing unifying narratives that inherently connect all things.

3. Nature Relatedness as a Core Psychological Need: Implications for Personal and Collective Behavior

There is some evidence to suggest that nature relatedness (NR), the sense of connection to the natural world [50], may be a basic human psychological need [51]. This may be mediated through documented mental health benefits, including reduced stress and anxiety, as well as many other physical, social, and emotional health benefits that contribute to general well-being. Importantly, access and connection to nature appear to buffer the adverse health effects of economic and social disadvantage [52,53]. A strong connection to nature has been associated with a greater sense of meaning and purpose in life and a source of spiritual connection and fulfillment [27–30] (Figure 2). Recognizing that Indigenous perspectives see all humans as inherently connected to nature, these Western constructs

of “connection” and “connectedness” speak to the perception of separateness or even exceptionalism. Ultimately, these perceptions must be addressed.



Figure 2. Restoring human connections to nature for personal and planetary health: stronger relationships with nature, especially in children, have lifelong implications for physical, emotional, and spiritual well-being as well as altruistic actions that protect the environment (art created by author S.L.P.).

With the world’s population now largely residing in heavily urban areas, there are significant implications of a “nature-deficit” for almost all aspects of human wellbeing [34]. Unequal access to quality green spaces appears to be an important factor that contributes to the social gradient in health inequities [54].

A connection to nature is also linked to health behaviors, including physical activity, coping with stress, social behaviors, and even dietary choices [35,55,56]. For example, NR was positively associated with dietary diversity and fruit and vegetable intake in an urban population [57]. In the context of the global crisis of lifestyle-associated noncommunicable diseases (NCDs), promoting positive behaviors through a connection to nature has clear implications for mitigating the spiraling personal, social, and economic cost of disease [34,58]. While nature-associated health benefits are complex and multifactorial, increased positive emotional assets appear to play an important role in promoting well-being, happiness, and life satisfaction [59–62]. This is highly relevant in addressing the growing spiritual crisis in many societies.

Moreover, self-awareness, mindfulness, and the ability to recognize and understand one’s own thoughts, feelings, and behaviors are associated with improved relationships, greater empathy, and compassion for others and for the natural world [25,39,63–68]. By extension and of relevance to the global sustainability agenda, a connection to nature is linked to altruism, volunteering, and other pro-social behaviors and pro-environmental actions [32,33,42]. Thus, efforts to “reconnect with nature” are not only logical countermeasures to address the mounting physical, mental and spiritual crises, but also to build more cohesive communities and collective actions for social and environmental change.

“What we achieve inwardly will change our outer reality” Plutarch, Greek Philosopher [69].

4. From Person to Planet: Making Connections Relevant, Meaningful, and Actionable

Complex problems require integrated thinking, awareness of interdependence, and worldviews that support actions spanning entrenched, siloed systems. The concept of planetary health is intended to unite the artificial compartmentalization of health at scales of “people” (so-called “individuals”), “places” (local environments and communities), and the “planet” [70,71]. This provides an ecological perspective that connects the health and

vitality of individuals, communities, and the Earth’s natural systems, including the social, political, and economic ecosystems that influence both individuals and whole societies. This underscores how the adverse macroscale ecology in the Anthropocene penetrates to the molecular level of personal and microscale ecologies, including the microbial systems at the foundation of all ecosystems [2]. The planetary health agenda seeks to place greater value on nature-based solutions and efforts to improve nature relatedness as crucial for restoring symbiosis, balance, and mutualism in every sense and to promote public awareness of a “personal” connection to the “planet.”

High-level directives to improve public health and/or environmental health are not effective without individual engagement and community resources. Similarly, individual efforts will not be effective in a hostile physical or social ecosystem. This means that both “grassroots” change and “top-down” solutions are required in tandem. We must seek to recognize the importance of individual and structural actions in making change and seek to align them. We must also include the value systems and mindsets necessary to promote mutualism, social responsibility, and environmental stewardship. Nature-based solutions and efforts to promote NR provide a logical nexus for co-creating meaningful local change and global impact.

The Sustainable Development Goals (SDGs) were adopted by the United Nations in 2015 to address the social, ecological, and economic dimensions of personal and planetary health. It has been argued that one of the key reasons for slow progress is the failure to address the mindsets and value systems that created the Anthropocene in the first place, as well as the relative underdevelopment of the inner growth, skills, and wisdom that are needed to manage the resulting complex challenges [72,73].

The recent IPCC 2022 Mitigation of Climate Change report identified the need to consider “inner transition” and shifts in personal and collective mindsets as part of efforts to advance sustainable transition strategies [74]. Increasingly, the United Nations and many governmental and non-governmental organizations recognize that inner development can contribute to understanding and facilitating sustainability not only at the individual level but also with respect to sustainability at all scales [19,75]. There are growing efforts to increase the focus on these links [17,76,77].

The Inner Development Goals (IDGs), founded in 2020, comprise one example which is rapidly gaining momentum [26,78]. This not-for-profit initiative was established to cultivate the skills and capacities needed to accelerate progress with the SDG. In addition to a personal focus, the IDG initiative is focused on promoting inner skillsets that can be applied in business, industry, government, and other non-government organizations. Based on an adult development model [79], the IDGs are composed of five clusters comprising 23 skills and qualities (Table 1) [26,78]

Table 1. The Inner Development Goals (IDGs) [26].

1. Being—Relationship to Self:	<i>Skills and Qualities:</i>
Cultivating our inner life and developing and deepening our relationship to our thoughts, feelings, and body help us be present, intentional, and non-reactive when we face complexity.	Self-awareness, presence, openness, a learning mindset, integrity, authenticity, and an inner compass.
2. Thinking—Cognitive Skills:	<i>Skills and Qualities:</i>
Developing our cognitive skills by taking different perspectives, evaluating information, and making sense of the world as an interconnected whole is essential for wise decision-making.	Critical thinking, complexity awareness, perspective skills, sense-making, long-term orientation, and visioning.
3. Relating—Caring for Others and the World	<i>Skills and Qualities:</i>
Appreciating, caring for, and feeling connected to others, such as neighbors, future generations, or the biosphere, helps us create more just and sustainable systems and societies for everyone.	Appreciation, connectedness, humility, empathy, and compassion.

Table 1. Cont.

4. Collaborating—Social Skills:	<i>Skills and Qualities:</i>
To make progress on shared concerns, we need to develop our abilities to include, hold space, and communicate with stakeholders with different values, skills, and competencies.	Communication skills, co-creation skills, an inclusive mindset, intercultural competence, trust, and mobilization skills.
5. Acting—Driving Change:	<i>Skills and Qualities:</i>
Qualities such as courage and optimism help us acquire true agency, break old patterns, generate original ideas, and act with persistence in uncertain times.	Courage, creativity, optimism, and perseverance.

There are many open questions regarding the concepts, methods, theories, and practical tools that can support these IDGs [80]. This is now the subject of an increasing amount of research aimed at assessing and optimizing efforts to influence values, mindsets, emotions, identities, wisdom, and intentions which can support and add to sustainable development at scale [80].

We propose that specific attention to the role of NR and efforts to increase a connection to nature should be a key element of this pursuit, particularly as NR has been associated with a) higher levels of many IDG skills and qualities (discussed further below) and b) higher levels of social and environmental responsibility and action.

5. Validated Measures of Nature Connection to Assess Meaningful Correlates with Physical and Emotional Assets, Health Behaviors, and Sustainability Behaviors

Concepts of nature connection arise from a subjective sense of nature connection with the natural world in terms of emotions, thoughts, and physical experiences. Specifically, this refers to a person's affective, cognitive, and physical relationship with nature or nurtured biophilia: the connections that human beings subconsciously seek with the rest of life. It is important to develop quantified measures in order to assess these relationships and potential changes with interventions.

A number of different measures are available, including nature relatedness (NR) [50], nature connectedness [81], and nature connectivity [82]. Most of these are fairly similar and consistent [83]. The example discussed here, the NR scale, was developed by one of the authors [50]. During the development of the score, an exploratory factor analysis identified three consistently emergent domains:

1. **The sense of self**, and how we see ourselves in relation to nature, e.g., the degree to which *"I feel very connected to nature and the earth"*, which is an example item developed for the questionnaire.
2. **Experience**, which refers to the degree to which people notice wildlife and enjoy spending time in nature, e.g., the degree to which *"I take notice of wildlife wherever I am."*
3. **Perspective**, an element very similar to other pro-environmental attitudes that assesses views on the rights of nature and human responsibility to live in harmony with nature, e.g., the degree to which people disagree that *"animals birds and plants should have fewer rights than humans"*.

This validated NR scale has been used extensively in research settings to examine relationships with various health outcomes, behaviours, and attitudes, revealing a number of important correlates.

Not unexpectedly, people who spend time outdoors, engaging with nature, have higher levels of nature relatedness and demonstrate higher measures of general health and mental well-being [27,84]. Early life experience of nature, such as growing up in a rural area, is also a particularly important predictor of higher NR scores in adulthood. There are also well-established relationships between contact with nature in children and cognitive performance, concentration, behavior, mood, anxiety, and other measures of

mental and physical wellbeing, including immune function and microbiome diversity (discussed further below and reviewed in [85,86]). This highlights the importance of early interventions in addressing the growing “nature deficit” in younger generations who are developing far stronger relationships with technology than nature [87–90].

There are also clear and consistent relationships between NR and positive emotions and happiness, including awe, relaxation, fascination, curiosity, excitement, and inspiration (reviewed in [30]). NR is also associated with lower levels of anxiety and arousal (reviewed in [38]). NR is also linked to a higher life satisfaction and a higher cognitive assessment of well-being. As an example, people with a high level of NR are also more likely to agree with the statement “*in most ways my life is close to my ideal*”. Importantly, many of these positive emotional assets are associated with biological markers of reduced inflammation [91] as a key predictor of long-term health.

NR is also positively associated with empathy, pro-environmental attitudes, and pro-social behaviors (higher humanitarianism and lower materialism) [30,35,92,93], as well as a higher concern for the sustainability of the natural environment [31,94]. NR is associated with stronger connections to abstract social groups (i.e., “all of humanity”) and distant others (such as a homeless person on the street) [95]. Children with greater experiential nature exposure are more likely to react to signs of environmental harm [96] and protect the environment in the future [97,98]. In at least one study, NR explained a high degree of variance in the ecological behavior of children (compared with environmental knowledge alone) [99]. Research by one of the present authors (from the Zelenski Lab at Carleton University) also suggests that it is possible to have pro-environmental attitudes *without* having a high sense of connection to nature, and that each independently add a significant predictive power to sustainable behaviours. In other words, it is not just the *belief* that the environment is under threat, but a sense of connection to the environment is also important to protect *action*. Thus, in a self-reinforcing way, engaging experiences within natural environments may help develop an emotional connectedness with nature and an enduring “environmental identity” [100,101].

Of relevance to promoting IDG from an early age, there is preliminary evidence that childhood nature exposure predicts adult emotional intelligence, creativity, and pro-environmental behaviours [102–104]. Findings suggest that children with lower levels of nature exposure grow up to exhibit a high tendency to miss subtle sensory stimuli, and that this sensory processing pattern, in turn, is associated with lower levels of affinity to nature and creativity [102].

Collectively, these observations suggest that improving nature relatedness could provide an important pathway to achieving many of the IDG objectives of “being, thinking, relating, collaborating and acting” towards the broader themes of the planetary health agenda. This includes promoting mindfulness through a connection to nature for more sustainable behaviours. In general, we have assessed broader eudemonic indicators of well-being (a wider realization of human potential) and observed that NR predicted a higher meaning in life; a sense of purpose, authenticity, and pro-sociality; greater generosity; and humanitarian attitudes (reviewed in [38]).

6. Can interventions Improve Nature Relatedness and Associated Attitudes, Behaviors, and Health Outcomes?

As NR is associated with so many positive outcomes, it is a logical target for improving well-being and quality of life—if we can increase it. This is a more challenging question which has not been definitively addressed. There are some indications of changes in NR with intensive interventions such as the 30 x 30 program in Canada, which involves people spending 30 min outside in nature every day for 30 days. While the increase in scores over the course of the study was suggestive, there was no control group for comparison (reviewed in [38]).

An important consideration is the distinction between “moment-to-moment” variations in scores and how this relates to underlying basic traits that may be less subject to fluctuation. Some items on the NR scale are not designed to detect short-term variations (e.g., *My connection to nature and the environment is a part of my spirituality* or *My relationship to nature is an important part of who I am*). To address this, one of the authors (at the Zelenski Lab) have performed a series of short-term experiments with control groups and measured a “momentary sense” of NR based on an adaption of the Inclusion of Nature in Self [INS] Scale [105]. We also examined the effects on individual NR scale items that are better at detecting short-term fluctuations in NR (e.g., *“In the last little while . . . I felt connected to all living things and the earth”*).

Interventions included physical activities, such as a 15-min nature walk, which consistently increased INS/NR scores compared to the control group, who took an underground tunnel walk. We also found that minimal mindfulness instruction also boosted people’s sense of connection to nature in the moment, highlighting the importance of the mental component [43]. We are now exploring how such momentary boosts in NR might lead to more sustained changes in NR and associated benefits.

In children, intervention studies show that time in biodiversity-rich environments can improve nature relatedness and psychological wellbeing in tandem [37]. We have also undertaken studies in children, comparing NR scores after undertaking a day in the forest versus responses after spending (a separate) day in an aviation museum. After a day in nature, the children reported a stronger sense of connection to nature and also a stronger interest in protecting nature [106].

There are also longer, more intensive nature-based programs in much younger children which demonstrate healthy changes in both health behaviours and environmental attitudes. One good example of this is the Nature Play and Grow program in Hong Kong, which also developed validated NR scales for very young children [107,108]. This randomized, controlled trial allocated 241 pre-schoolers and their families to either a control group or a 10 week program of outdoor play and nature discovery, age-appropriate, short health and environmental discussions, and food play activities. This was shown to improve dietary habits and exercise among parents and children in the same household. Specifically, after the trial, those in the intervention group were more active and had improved eating habits, behaviour, quality of life, and physical functioning. Moreover, they were more connected to nature (measured as a sense of environmental responsibility) compared with the control group [108]. Importantly, given the emerging relationship between nature exposure and the developing microbiome (discussed further below), it was notable that the children in the intervention group had measurable changes in their gut microbiota [109,110].

This underscores the importance of early life education and early interventions, which may have lasting lifelong implications for health behaviors and environmental attitudes [104,111,112]. While there is evidence that environmental education programs can achieve short-term increases in nature connection scores in older children, this appears to be more sustainable before the preteen years [113].

We (at the Zelenski Lab) are conducting exploratory studies to determine whether these relationships also operate in the reverse direction. In other words, one path to feeling more connected to nature might also begin by engaging in pro-environmental behaviors. So, rather than hoping that the pro-environmental behaviors follow a connection to nature (and inner development), we may hope that encouraging pro-environmental behaviors will also lead to inner development with changes in attitudes and mindfulness toward greater consciousness-driven transformations.

Finally, in addition to targeted interventions for personal health, interventions at the neighborhood and community levels may be beneficial for both individuals and wider social cohesion [40,41], especially those promoting equitable access to green spaces [54].

7. Inner and Outer Ecosystems: Microbial Pathways Blur the Artificial Divisions between Personal and Planetary Ecology

Microbial systems provide another perspective on how, quite literally, our inner and outer ecosystems are connected, and how our actions and behaviors can affect both these inner and outer worlds in ways that influence health on all scales. These concepts have already transformed how we view the human “self” and have helped to erase the imaginary dividing line between the biological and psychological [114,115].

Microbes connect the health of all ecosystems, from soil systems and climate systems to the health of each individual living organism [116]. These foundational interrelationships provide tangible biological pathways for interdependence and suggest new avenues for ecological approaches and working *with* nature to promote the flourishing of all organisms and systems. Furthermore, these concepts support new narratives that promote an awareness of the many ways in which “planetary health is personal.”

There are now well-documented links between human skin and gut microbiome signatures and contact with nature (greenspaces, vegetation, soil, and other forms of biodiversity) [117–119]. The critical influence of these microbes on physical and mental health may be one important pathway that mediates the health benefits of spending time in and engaging with nature [117]. This includes the effects of microbes and their metabolites on myriad host immune, metabolic, and neuroendocrine functions.

The adverse effects of human activity on macroscale ecology penetrate down to the molecular level, demonstrating a reduced microbial diversity and evidence of the “extinction” of critical microbes in Western populations compared to traditional communities [120–123].

The degradation of natural environments and food systems and urban living conditions all impact personal microbial ecology (reviewed in [2]). For example, air pollution [124], environmental toxins [125], psychological stress [126,127], ultra-processed food [128] dietary advanced glycation end-products [129], emulsifiers [130], phthalates [131]), sleep disruption [132], tobacco use [133], sedentary behavior [134], excess alcohol consumption [135], and the over-prescription of antibiotics [136] have been shown to impact the microbiome. These effects are magnified in socioeconomically disadvantaged and marginalized populations [137–141]. Indeed, it is becoming increasingly evident that the links between microbes and social equity issues are multifold. Important research questions have been identified to help articulate these social issues from a microbiological perspective and to bridge the most salient knowledge gaps with the ultimate goal of improving community livelihoods [142].

The collective adverse shift in ecology at all scales in the Anthropocene has been described as “dysbiotic drift” [143]. It is directly implicated in the mounting global burden of NCDs (Figure 3) [144,145]. These effects on both physical and mental health are mediated through immune and metabolic dysregulation across lifespans and are amplified by socioeconomic disadvantage [137–141]. Most notably, the ecology of the early life environment, including contact with nature, microbial diversity, nutrition, and social interactions, have lifelong implications for all aspects of health and resilience [144].

Thus, our individual and collective choices have a powerful effect on ecology at both the microscale and the macroscale, with intertwined implications for both personal and planetary health. This awareness has strengthened the call for ecological solutions—working *with* nature—as the most logical strategies to ameliorate dysbiotic drift and disease at all scales [2,146,147].



Figure 3. “Dysbiotic Drift” requires ecological solutions: Mass urbanization, unhealthy lifestyles, and environmental stress has led to progressive dysbiosis (life in distress) across all scales, including the personal microbiomes that are vital for health. Nature-based solutions will be required for “rewilding” biodiversity to restore health across the personal to planetary health continuum (art created by author S.L.P.).

8. Microbiomes and Altruism: Exploring Novel Links between Microbial Biodiversity, Neurobiology, and Prosocial Behavior

In addition to well-documented relationships with mood, anxiety, and stress responses [148], there is growing evidence that microbiota also influence empathy, self-judgement [115], and social behavior [149–151]. Extensive studies have demonstrated how gut microbes influence sociality and behavior through numerous neurobiological pathways in the brain [149]. This includes signaling pathways of the “love hormone” oxytocin, a neuropeptide hormone largely produced in the hypothalamus which is related to sociability and well-being [149–151]. Oxytocin plays a prominent role in social attachment beginning with the mother–infant bond. This provides a fascinating new biological dimension to how contact with biodiversity may affect or mediate well-being, social relationships, and even altruistic behaviors.

Oxytocin is also related to spirituality and is associated with feelings of love and trust. It has been shown to increase during meditation and religious practices [152,153]. Human research volunteers who receive oxytocin experimentally (e.g., via nasal administration) report experiencing spiritual emotions, including awe and gratitude [154]. Oxytocin also appears to increase empathy [155] and altruism [156].

Given the clear evidence that the gut–brain axis influences behavior, these neuroendocrine pathways have also been explored in animal models, showing consistent links between oxytocin and disruptions in the microbiome. Depletion of the microbiome (with antibiotics or with maternal high-fat diets in pregnancy) results in social impairment and fewer hypothalamic, oxytocin-expressing neurons [157]. The administration of probiotic bacteria (notably *Limosilactobacillus reuteri*, a bacterium isolated from breast milk) restores oxytocin levels and social behaviors [157]. Other studies have shown that *L. reuteri* consistently and significantly increases oxytocin levels and suppresses glucocorticoid signaling (reviewed in [149,150,158]). There is also evidence that the microbiome can regulate social behaviors through discrete neuronal circuits that mediate stress responses in the brain [159] and via the immune system, which mediates vulnerability and resilience to stress by regulating the hypothalamic–pituitary–adrenal axis [160]. Indeed, studies indicate that inflammation can contribute to the onset of stress-related neurological disorders, including depression, anxiety, and drug use [161,162]. Functionally diverse microbiota are required to supply life-sustaining metabolites (such as short-chain fatty acids) that regulate inflammation and cell signaling in the human “walking ecosystem” [163]. Therefore, eubiosis

(the state of having a balanced microbial community) is likely important for ameliorating neurological disorders and thus influences a range of social behaviors.

Overall, the experimental literature indicates that the microbiome affects social behavior and that normal social function requires the presence of a microbiome [149]. While this is much harder to assess in humans, there is some evidence that gut microbiome patterns in young children (decreased abundance of *Prevotella*) are associated with emotional and behavioral problems [164,165], and that these can improve with microbiota transfer therapy [166]. In adults, microbiome interventions (probiotics or fermented foods) have been shown to modify brain function (assessed by neuroimaging methods) [167,168], enhance vitality, reduce mental fatigue, and modulate neural responses during social stress [168]. Human microbiome signatures and measures of inflammation are also associated with negative self-judgment and lower empathy [115]. This warrants further investigation and new perspectives on how microbes, as partners in our physical and social evolution over millennia, have shaped both biology and behavior [169].

Collectively, these observations raise interesting questions about the role of “dysbiotic drift” and declining social cohesion at scale. In particular, aggressive behaviors have been linked to microbiome changes with calorie-dense, innutritious, ultra-processed Western diets [170]. Again, this indicates the personal and social value of promoting engagement with healthy green and blue spaces to improve human microbiomes directly [117] and indirectly through healthy dietary choices [57].

9. Implications of Germaphobia, Nature-Aversion and Extinction of Experience in the Post-COVID Era

Ecologist Dr Robert Pyle coined the term “extinction of experience” in 1978 [171] based on concerns that loss of direct, personal contact with biodiversity might lead to emotional apathy and irresponsible behaviors toward the environment [171,172]. Since then, both adults and children in Westernized nations are spending even more time indoors [173–175], with age-related, cross-generational declines in childhood experiences with nature [176]. The increasing use of screen-based technology has been a significant factor in diminished time outdoors in natural environments [87–90]. There are also indications that environmental degradation and local biodiversity losses may be further contributing to the preference for time indoors [177].

The COVID-19 pandemic has had far-reaching effects on many aspects of health and behavior, including time in nature, exercise and dietary patterns, and attitudes toward microbes [178–181]. The acute events of the pandemic (e.g., lockdowns) resulted in significant but variable local and regional changes in access to nature with additional socio-economic and age-related variations [178,182,183]. The frequency, duration, and quality of nature interactions dropped during the lockdown in some urban settings, particularly in the least green neighborhoods, where decreases in personal and social well-being were more evident [178]. While lockdown measures were temporary, the long-term effects in increasing “germaphobia” on relationships with nature remain a concern.

To address this, a recent study by one of the current authors (J.M.R.) explored the relationship between attitudes toward microbes and visits to natural environments. In this sample of 1184 participants, mostly from the United Kingdom, we found that people with more positive attitudes to microbes visited natural environments (such as woodlands, parks, and meadows) significantly more often ($p < 0.01$) and spent significantly more time in nature per week ($p < 0.01$) [184]. We found that attitudes towards microbes were associated with “microbial literacy” (knowledge and basic understanding of different kinds of microbes) [184]. These results suggest that germaphobia-related attitudes may reduce the desire to spend time in nature, although it is also possible that spending time in nature creates more positive attitudes toward invisible biodiversity.

The persistent, widespread (i.e., non-targeted) and increased use of sanitizers and disinfectants raises additional concerns regarding their effects on personal and environmental microbiomes. The pre-existing “biological extinction of experience” with dysbiotic drift contributed to the physical, emotional, and social health consequences of the mounting NCD pandemic over the last 50 years [185,186]. This crisis of inflammatory disease is at least partially driven by the absence of immune system “experience” with biodiversity, notably microbes from natural environments [185,186].

A greater emphasis on microbiological literacy and connections to human health will promote constructive attitudes and engagement with nature, especially in the context of the growing pathological aversion to microbes. We (Robinson and colleagues) are working on a microbiology education framework to reframe this narrative and promote awareness that less than 0.1% of all microbial species are human-associated pathogens and that many microbes are essential for our wellbeing and survival.

Thus, it is important to integrate the previously separate and parallel discussions on the “psychological” [171,172] consequences of the extinction of experience and the “biological” consequences outlined in the “biodiversity hypothesis” [187,188], which underscores microbial “extinction” and dysbiosis as common denominators in the unprecedented global rise in chronic physical and mental disease [71].

10. Nature-Based Solutions and Microbiome-Inspired Infrastructure

Nature-based solutions provide practical, tangible ways for individuals and communities to make a meaningful difference to their own health, their community, and the wider environment (Figure 4). In addition to the restoration of natural habitats, such as forests and wetlands, this also includes incorporating natural features and processes into urban landscapes, buildings, and infrastructure.



Figure 4. Nature-based solutions to improve personal and environmental ecology: These include a variety of measures ranging from urban greening, regenerative agriculture, and microbiome-inspired green infrastructure to green prescriptions to encourage nature-based personal activity (art created by author S.L.P.).

This extends to more ecological approaches to agriculture, food production, and waste management. The European Commission recognises that solutions “*inspired and supported by nature . . . are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience*” [189]. At the local scale, community efforts to “green” blighted urban lots demonstrate multiple benefits for physical and mental health, as well as improved community safety and cohesion and less crime, violence, and fear [40,41]. Even in prisons, nature-based activities improve NR, behavior, and relationships and reduce infractions (discussed [190]).

These practical strategies also build optimism, motivation, and engagement in efforts for sustainable change [11]. Urban “rewilding” also includes strategies for more biodiverse environmental microbiomes. This is the basis of microbiome-inspired infrastructure (MIGI): considering microorganisms and their associated ecosystems in the design and operation of built environments [191]. MIGI is the collective term for living, multifunctional green spaces that are designed, restored, and sometimes managed to generate health-inducing microbial interactions, as described by co-author J.M.R. in more detail elsewhere [117,146]. This includes strategies for healthier soils, vegetation, air quality (aerobiomes), waste treatment, energy generation, and using more bioreceptive materials and bio-integrated design [146]. Microbiomes can also play a role in the health and functioning of buildings. In an encouraging example, indoor air-circulating “green walls” have been shown to increase bacterial abundance and diversity on the skin of office workers with an associated lowering of proinflammatory blood cytokine measurements [192]. In children, using microbiome-enriched soils (from forest floors) in daycare yards increases both environmental and skin microbial diversity which, in turn, is associated with favorable immunological effects [193]. Specific soil microbes (such as *Mycobacterium vaccae*) are even being explored as potential therapeutics for mental health disorders (discussed at length in [194]).

Nature-based solutions also include “green prescriptions,” education, and other integrative strategies to promote co-benefits for personal, public, and environmental health [195,196]. These can include green exercise, mindful nature connections, wilderness art, therapeutic horticulture, biodiversity conservation, care farming, and nature play for children [196]. As described above, these kinds of activities promote nature relatedness and improve dietary habits, stress, activity, and attitudes toward the environment with measurable changes in the children’s gut microbiota [109,110].

This is akin to longstanding traditions such as *shinrin-yoku*, which means “forest-air bathing” or “absorbing the forest air”, a practice that recognizes the holistic experience of all the “components emitted from the forest” [197]. In addition to the psychological benefits, these immersive forest experiences have been shown to have biological effects on stress physiology, cytokines, and other markers of inflammation, immune parameters (e.g., natural killer cells), blood pressure, and heart rate variability [198]. These changes are likely to be mediated through multiple pathways, including effects of nature on personal biodiversity [117].

Nature-based solutions and efforts to improve nature relatedness are crucial for restoring symbiosis, balance, and mutualism in every sense—physical and social—along the personal, community and planetary health continuum. A final note on nature-based solutions: this term implies an instrument-centric perspective of nature, but it is vital that nature-based solution narratives are reshaped to also recognize the intrinsic value of nature and, as previously stated, to adopt a ‘working *with* nature’ approach.

11. Mutual Reawakening: Nature and Art-Based Invitations for Personal Growth and Community Building

Recognizing the importance of nature and creativity for personal growth and community building, the Mutual Reawakening Project was established to explore visions, stories, and experiences of human and planetary healing in the context of current environmental upheaval. Funded by the Nova Institute for Health under the direction of one of the present authors (S.W.), this project seeks to inspire others to imagine new ways of living and create a vision for transformative action [199,200]. The transdisciplinary project team comprises a diverse group including physicians, an environmental psychologist, a medical anthropologist, graphic designers, community artists, curators, and writers.

The project comprises multiple methods of engaging people with nature, including:

- (a) **A pilot study of forest therapy** based on notions of forest bathing and *shinrin-yoku* (a 2–3 h sensory experience in nature). This practice focuses on mindful awareness of nature through the key senses: smell, taste, touch, hearing, and vision;

- (b) **Nature- and arts-based facilitated group activities** based on sharing the personal experiences, reflections, and artistic creations made during individual nature experiences;
- (c) **An art exhibition on planetary health** for hospital audiences. This will comprise photographs inspired by mindful connections to nature. These will be initially displayed at the University of Michigan Hospital with plans to travel to other health centres across the United States;
- (d) **A commitment to sharing more widely:** the team hopes to inspire others to engage in similar activities through social media engagement and the art exhibition in addition to traditional academic communications.

The nature- and arts-based invitations began during the pandemic in 2020 on the 50th anniversary of the first Earth Day. The project began with a simple invitation during the lockdowns (see Table 2). This provided the inspiration to expand our team and develop this nature-based experience with more structure, to inform gatherings, and to share more widely with others. The team leadership began with the sensory emphasis of *shinrin-yoku* and included a more systematic approach to focus invitations on key elements of nature (e.g., wind, water, earth, and fire) and align the schedule with key times in the Earth's cycle (e.g., the equinox, solstice, and other ancient ceremonial times of the year) to promote a personal and planetary level sense of awareness and connection.

Table 2. Examples of the nature and art-based invitation (some responses are on the Mutual Reawakening website [199]).

Connection:
<p>The initial invitation to connect: “Find a posture that feels comfortable, give yourself some time to settle into place, take a couple of long breaths, and focus on relaxing your body and allowing the earth to hold you. Breathe into your heart space and bear witness to whatever arises from the earth and from within yourself. Do this for as long as you like”.</p> <p>A subsequent example invitation: “Find a place to walk barefoot on an outdoor textured surface. You are invited to notice the way the surface feels on the soles of your feet”</p>
Reflection:
<p>Participants invited to reflect and respond by making something: “A drawing. A memo. A video. A song. And respond to these questions: What are you noticing? What does it mean to live well on Earth now?”</p> <p>Example of a subsequent invitation: “Find five words, phrases, or sentences to describe your sensations. What else is moved in you?”</p>
Share a creative expression:
<p>Participants were then invited to share: a photo of their nature spot and share their creations, and reflections with the group. As this process evolved, the team leadership incorporated sharing into a facilitated interactive virtual group circle activity.</p>

Participants all reported finding this very nourishing, both through the personal connection with nature and the process of sharing the experience in a community. These exercises were of great value in helping people cope with the demands of everyday life and provided a common ground for engagement with the team working together. Some of the evaluation comments included:

“I’m amazed at how quickly I can feel connected to the other beings on the planet. A deep sense of peacefulness right down to my soul. A sense of stillness. And appreciation of giving myself the time to be present in the moment.”

“Connect with nature, connect with self. Relaxed, mindful. Bring a different self to the work: more authentic, more open.”

“the prompts [are] creating our ‘community’ of dreamers, furthering our work together ... [and we] ... solidify for ourselves what it is we love and what value it has for us in terms of our wholeness, health and well-being.”

The Mutual Reawakening team plans to develop and evaluate this exploratory study further. While this simple invitation specifically targeted a professional women's group, it can be readily adapted to other groups and settings and provides an example for others.

12. Conclusions: Calling for More Integrated, Creative, and Heart-Centered Approaches

The ecological lens provided by nature encourages integrated perspectives that recognize interdependence and interwoven complexity. While reductionist approaches have been successful in many fields, there are clear limitations to the highly complex and multifaceted erosion of physical and spiritual environments in many modern societies [201,202].

Exploring the nexus of inner and outer sustainability is also not exclusively an intellectual exercise. More holistic approaches should also consider the emotional and subjective aspects of these issues, especially as many of our current problems can be considered relational problems, i.e., unhealthful attitudes and relationships with the self, others, and the natural world [5].

Encouraging open-mindedness and normalizing more creative, heart-centered approaches is crucial to the personal and collective sustainability agenda, including the importance of personal values, belief systems, wonder, inspiration, and other positive emotions in empowering change [20]. The academic enquiry that has traditionally diminished, stifled, or dismissed the emotional and spiritual dimensions of these issues may lead to a narrow or incomplete understanding of the problem and limit potential solutions [203]. In addition to promoting kinder, more heartfelt, positive, and productive environments for learning, growth, and discovery, this is also more likely to encourage wider community engagement, belonging, purpose, and meaning.

Integrating the biological dimensions of nature interactions and positive emotions, as we have done here, is also an important way to strengthen and align social and ecological systems. Our focus on the microbiome provides a key narrative to open a door of awareness to the very personal, biological consequences of large-scale biodiversity loss [71]. Similarly, the positive emotions inspired by nature are associated with markers of reduced inflammation [91], which is another predictor of longevity and all-cause mortality [204]. Further work is important to further understand these relationships and reinforce the connections between the “psychological” and “biological” benefits of nature-based strategies.

We also seek to reinforce the concept that all these benefits of connectivity to nature are particularly important in childhood, with clear implications for long-term physical and mental health outcomes, environmental attitudes, and even microbiomes. It is important that these efforts are particularly focused in early life, when lifelong biology and behaviours are established, including physiology, microbial ecology, stress responses, health behaviours, social relationships, and altruism [205]. Since time spent in and engaging with nature in early life predicts later-life engagement in nature-based activities [206–209] and subsequent pro-environmental attitudes (and quite likely, pro-environmental behaviors) [97,98], promoting a connection with nature in the next generation should be an important, shared priority in integrating the health and sustainability agendas.

Finally, we hope that these discussions lead to a deeper collaborative exploration of human consciousness and our connection to all things, and that we may learn to use our knowledge more wisely. For thousands of years and from countless cultures, the gentle message has been the same: we need to look *within* to find the answers to life.

“Humanity has only scratched the surface of its own potential” Peace Pilgrim [210]

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