Our Health and Environmental Microbial Biodiversity

The Health Benefits of Green Space — Psychology or Biology?

Text and images by Graham Rook

I shall soon be rested,” said Fanny; “to sit in the shade on a fine day, and look upon verdure, is the most restful enjoyment.” —Fanny Price, in Chapter 9, Mansfield Park, by Jane Austen, published in 1814

Introduction

We all accept the notion that exposure to the natural environment, or to gardens and parks can be beneficial. Indeed, large epidemiological studies demonstrate that living close to natural or coastal environments, and depressive symptoms increases subjective feelings of well-being (Maas et al. 2006; Mitchell and Popham 2008; Wheeler et al. 2012). These beneficial effects are particularly prominent in urban individuals of low socioeconomic status who tend to be most severely deprived of green space (Maas et al. 2008; Lachowycz and Jones 2014). Another possibility is that proximity to green spaces correlates with less exposure to traffic pollution, but a recent study has found that reduced pollution only explains a small part of the observed benefits (Dadvand et al. 2012; Wheeler et al. 2012).

If asked why these effects occur, most people would implicate relaxation, sun, and exercise. However, recent work suggests that the answer is more complicated than that. Here, I will first explain the information gaps in the current concept, then introduce a new candidate: exposure to microbial biodiversity, which is rendered essential by our evolutionary history and by the workings of our immune systems. This issue is important because the more we understand the mechanisms of the health benefits of green space, the more efficiently we can exploit them for human well-being.

Some proponents of the view that the benefits are due to psychological and physiological changes that can be demonstrated after short exposure to parkland and forests. This rapid effect can be proven not only by psychological testing (Berman, Jonides, and Kaplan 2008), but also by mobile electroencephalographs (Aspinall et al. 2013) and by measurements of cerebral blood flow, various cardiac parameters, and salivary levels of “green space” or “blue space” respectively, reduces overall mortality, cardiovascular disease, and depressive symptoms and increases subjective feelings of well-being (Maas et al. 2006; Mitchell and Popham 2008; Dadvand et al. 2012; Wheeler et al. 2012). These beneficial effects are particularly prominent in urban individuals of low socioeconomic status who tend to be most severely deprived of green space (Maas et al. 2006; Mitchell and Popham 2008; Dadvand et al. 2012; Wheeler et al. 2012).

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We’ve seen that in high-income urban communities, the immune system makes two types of mistakes. First, it attacks things like our own tissues that it should not attack, and second, it fails to turn off background inflammation when it is not needed. This is a concern as inflammation is metabolically costly and, in the long term, dangerous.

Why Are Urban Immune Systems Prone to Overactivity?

Why is the modern urban immune system functioning incorrectly? At birth, the immune system is like a computer that has hardware (structural components) and software (genetic programmes) of almost no data (See Fig. 2). In order to function correctly, the immune system must acquire these data, preferably during the early years of life. The sources of the data are the various classes of microorganisms with which humans co-evolved. So what are these microorganisms, and why are they now absent or depleted such that our immune systems do not have all the data they need?

Our Symbiotic Microbial Partners

We tend to think of humans as individuals. In fact, humans, like all vertebrates, are ecosystems. We are hosts to a huge and diverse community of microorganisms (the microbiota), particularly in the gut. In fact, only about 10 percent of our cells are human, and less than 1 percent of the genes that control our development, physiology, and health are situated in the human genome inside our human cells. Most of “our” genetic material is located in the organisms that constitute our microbiota. This microbiota, notably the gut microbiota, influences the development of most, or perhaps all, of our organ systems (McFall-Ngai et al. 2013; Gilbert, Sapp, and Tauber 2012). For example, in germ-free animals artificially created by caesarean section in sterile laboratories, the brain fails to develop normally, and human experiments have shown that the gut microbiota influences aspects of cognitive development in emotion and sensation (Tillisch et al. 2013). Similarly, we now know that there is a critical period during infancy when the composition of the microbiota determines the long-term function of the immune system and the balance of metabolic pathways. If the microbiota is defective at this critical time (for example, due to heavy antibiotic consumption), the animal grows up with a tendency to inflammation and obesity—which are crucial correlates of malfunction of these two systems (Cox et al. 2014).

Loss of Biodiversity: Consequences for Human Health

It is not only in childhood that the composition of the microbiota is important. Gut microbiota of abnormal composition, or of limited diversity, is characteristic of conditions associated with human inflammation (Turnbaugh et al. 2009; Fehman et al. 2010) and often associated with poor control of inflammation in experimental animals (Hildebrand et al. 2013). Similarly, diminished, microbiota biodiversity in institutionalised elderly people correlates with raised levels of markers of inflammation in the blood and declining health (Claesson et al. 2012). So the microbiota is essential not only for the development of our organs, but also for their continuing healthy function.

Where Do Our Microbiota Come From, and What Goes Wrong in Cities?

Humans and other mammals initially obtain many of the microorganisms that constitute their microbiota from their mothers’ faecal and vaginal microbiota during delivery, and via breast milk, which is not sterile (Cox et al. 2013), and from family members. In fact, breast milk contains “prebiotics”. These are polysaccharides that cannot be metabolised by the baby, but are present in the breast milk to nourish and encourage certain types of bacteria in the infant gut (Garrido, Barile, and Mills 2012). Interestingly, the prevalence of allergic eczema is reduced in babies whose mothers suck the pacifier (dummy) clean after it has fallen on the floor than place it in the baby’s mouth, compared to the incidence in those whose mothers provide them with a new sterile one (Hassalmir et al. 2013). Modern non-behavioural practices tend to limit this crucial transfer of microbiota from the mother to the baby. Canadian delivery, lack of breast-feeding, antibiotics (Rook, Raison, and Lowry 2014), and increasing uniformity of diet (Khoury et al. 2014) all aggravate the problem.

However, the mother is not the only source of microbiota. Many, or probably all, animal species including humans obtain components of their microbiota from soil and the natural environment (Troyer 1984; Mulder et al. 2011). It is very probable that geophagy (or the eating of soil) by babies and infants is an evolved strategy for the uptake of soil organisms. This is manifested as the “oral” phase of development, when all babies put whatever they can reach into their mouths. The quantities of soil and faecal matter that can be ingested by human babies with access to these materials (for example, in an African village) are astonishing (Nigue et al. 2013).

Health Benefits of Exposure to Animals in the Environment

Some of the relevant microbiota come from animals. Contact with dogs, with pigs protects against allergic disorders (Riedler et al. 2001; Radon et al. 2007). This protection appears to be attributable to airborne microbial biodiversity that can be assayed in children’s bedrooms (Ege et al. 2011). Similarly, more proximity to agricultural land rather than urban agglomerations increased the biodiversity of skin microbiota, reduced atopic (or allergic) sensitisation, and increased the release of IL-10, an anti-inflammatory mediator, by blood cells (Hanski et al. 2012). Soil is not the only non-maternal source. Evidence that humans acquire important microbial biodiversity from the environment comes from studies of the effects of contact with farms, animals, and green spaces. Exposure of the pregnant mother or infant to the farming environment protects the child against allergic disorders and juvenile forms of inflammatory bowel disease (Riedler et al. 2001; Radon et al. 2007). This protection appears to be attributable to airborne microbial biodiversity that can be assayed in children’s bedrooms (Ege et al. 2011). Similarly, more proximity to agricultural land rather than urban agglomerations increased the biodiversity of skin microbiota, reduced atopic (or allergic) sensitisation, and increased the release of IL-10, an anti-inflammatory mediator, by blood cells (Hanski et al. 2012).

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Gut Microbiota in the Green Environment

Another fascinating issue is the role of spore-forming bacteria that are usually considered to be soil organisms, but which can germinate and replicate in the human gut (Hong et al. 2009; Rook, Raison, and Lowry 2014). About one-third of the species that constitute the human gut microbiota are spore-forming. Spores are astonishingly resistant and can persist in the environment for tens of thousands of years. So wherever humans (or other vertebrates) have been in the past, gut-adapted spore-forming strains have been seeded into the environment via faeces and are waiting there as spores, ready to be picked up by newly arriving humans and soil-eating babies! We do not currently know how much of the human microbiota is derived from the microbial environment. Though work on this point is in progress, the overlaps between gut and soil or plant root microbiota have been discussed (Ramazeb-Puebla et al. 2013). Germ-free mice readily develop a functioning gut microbiota following exposure to microbial communities from soil (Seedorf et al. 2014).
Mechanisms of Green Space Health Benefits

**Biological**
- Need for diverse microbial input to immune system
- Increase microbial load & biodiversity in home
- Microbial biodiversity
- Exchange of microbiota
- Vitamin D improves regulation of immune system
- More immunoregulation

**Psychological**
- Walk in green space
- Dogs
- Social interaction
- Sunlight
- Exercise
- Health benefits, weight loss

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**References**


