

THE ROLE OF ENVIRONMENTAL MICROBIOTA IN SHAPING HUMAN GUT HEALTH: ECOLOGICAL PERSPECTIVES

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Abstract: The human gut microbiota plays a central role in maintaining health by influencing immune regulation, metabolic functions, and susceptibility to diseases. Environmental microbiota—microbial communities present in soil, air, and water—play an important role in shaping the composition and functionality of the human gut microbiota. However, urbanization, industrialization, and modern lifestyles have significantly reduced human exposure to these environmental microbes, leading to a decline in microbial diversity and associated health risks. This paper explores the pathways through which environmental microbial communities interact with the human gut microbiota, analyzes the impact of urbanization on microbial diversity, and evaluates the related health effects. Key mechanisms linking gut dysbiosis with diseases such as autoimmune disorders, allergies, and metabolic syndromes are highlighted. In addition, potential interventions, including urban greening, traditional dietary practices, and engineered probiotics, that may compensate for microbial loss are discussed. Finally, knowledge gaps are identified, and directions for future research are proposed to deepen the understanding of microbial ecosystems and their role in human health.

Keywords: environmental microbiota, gut health, microbial diversity, urbanization, human microbiome, ecological perspectives.

Introduction

The human gut microbiota consists of trillions of microorganisms that participate in digestion, immune regulation, metabolism, and protection against pathogens (Lynch & Pedersen, 2016). Although genetic and dietary factors play a significant role, environmental exposure is one of the most important determinants of gut microbiota diversity. Microorganisms present in soil, water, and air form an extended ecological reservoir that influences the development and stability of the gut microbiota throughout the human lifespan (Dominguez-Bello et al., 2019).

However, rapid urbanization and changes in modern lifestyles have significantly reduced human contact with natural microbial sources. This has led to a decline in microbial diversity, which, in turn, is associated with an increased prevalence of immune disorders, allergies, asthma, and metabolic diseases (Blaser, 2016). This study analyzes the ecological mechanisms of interaction between environmental microbiota and the human gut microbiota, evaluates how urbanization

disrupts these processes, and considers potential strategies for restoring microbial diversity.

Materials and Methods

This study is based on a structured qualitative literature review. Search queries were conducted in the PubMed, Google Scholar, Scopus, and Web of Science databases using keywords related to environmental microbiota, gut health, microbial diversity, urbanization, dysbiosis, immune regulation, and ecological impact. Studies published between 2010 and 2024 were included if they provided empirical data or high-quality observational findings relevant to the interaction between human microbiota and the environment. Foundational studies published before 2010 were included when necessary to clarify theoretical aspects.

Articles focusing exclusively on animals without practical relevance to humans, as well as publications with insufficiently described methodology, were excluded. The extracted data were organized thematically into the following categories: pathways of microbial exchange, the impact of urbanization, health consequences of reduced microbial diversity, and strategies to enhance microbial resilience. Due to the heterogeneity of study designs, a qualitative descriptive synthesis was applied rather than a quantitative meta-analysis.

Results

3.1. Pathways of Microbial Exchange

3.1.1. Dietary Pathway

Diet has proven to be one of the most stable and significant pathways linking environmental microbiota with the gut microbiota. Diets rich in natural dietary fiber and fermented foods increase microbial diversity by providing substrates that stimulate the growth of beneficial bacteria and support the production of short-chain fatty acids (Arrieta et al., 2014). Comparative studies show that children in rural areas of Burkina Faso, who consume minimally processed, fiber-rich diets, possess significantly more diverse gut microbiota than urban children whose diets are dominated by refined sugars and fats (De Filippo et al., 2010). This indicates that traditional dietary practices maintain a closer connection with natural microbial sources.

3.1.2. Physical Interaction with the Natural Environment

Direct physical contact with soil, plants, and animals facilitates the entry of a wide spectrum of environmental microbes into the human body. Studies conducted in agricultural settings demonstrate that regular interaction with agroecosystems enriches the human microbiota and reduces the likelihood of developing asthma and allergies. The immunomodulatory effects observed in children raised on farms highlight the importance of continuous eco-microbial contact for the formation of a resilient immune system (Stein et al., 2016).

3.1.3. Airborne Transmission

Airborne microbes originating from biodiverse natural ecosystems also represent an important route of microbial exchange. Finnish studies demonstrate that individuals living near forests and natural green areas exhibit greater diversity of skin and gut microbiota compared with residents of urbanized environments. They also show lower levels of inflammatory biomarkers, confirming the significance of airborne microbial exposure for immune regulation (Hanski et al., 2012).

3.2. Impact of Urbanization on Microbial Diversity

Urbanization significantly alters the processes of microbial exchange between humans and the environment. Limited access to natural green spaces reduces contact with soil- and plant-associated microbes (Rook, 2013). In addition, the widespread use of disinfectants and antibiotics disrupts microbial transmission and weakens gut microbiota diversity (Blaser, 2016). Dietary shifts characterized by high consumption of ultra-processed foods and low fiber intake further contribute to microbial depletion (De Filippo et al., 2010). The cumulative effect of these factors leads to ecological imbalance, influencing public health on a global scale.

3.3. Health Consequences of Reduced Microbial Diversity

3.3.1. Immune Dysregulation

Reduced microbial exposure during critical periods of development disrupts the formation of immune tolerance. Insufficient microbial diversity in early life is associated with a higher incidence of autoimmune diseases, including type 1 diabetes mellitus and inflammatory bowel diseases (Dominguez-Bello et al., 2019).

3.3.2. Metabolic Disorders

Dysbiosis leads to impaired metabolic health. Individuals with obesity and type 2 diabetes mellitus exhibit reduced gut microbiota diversity and decreased production of short-chain fatty acids, which play a key role in the regulation of glucose and lipid metabolism (Qin et al., 2012).

3.3.3. Allergies and Asthma

The rising prevalence of allergic diseases is closely associated with reduced contact with environmental microbes. Children raised in agricultural environments demonstrate significantly lower rates of asthma and allergies compared with urban children, confirming the protective role of ecological microbes (Stein et al., 2016).

. Discussion

The present review demonstrates that environmental microbiota serve as an essential ecological partner, exerting a substantial influence on the composition of the human gut microbiota and overall health. The identified exchange pathways—dietary, ecological, and airborne—highlight the importance of maintaining human connection with natural ecosystems. A traditional lifestyle that includes regular outdoor activity, balanced nutrition, and limited use of antibiotics contributes to the development of a resilient microbiota.

However, modern urban conditions disrupt these processes. Reduced contact with nature, the sterility of urban environments, and the widespread consumption of processed foods lead to decreased microbial exposure and subsequent development of dysbiosis. Loss of microbial diversity increases susceptibility to immune, metabolic, and allergic diseases.

Several strategies show promise in restoring microbial balance. Urban greening initiatives promote the reintroduction of biodiverse microbial communities into everyday environments. Probiotics and prebiotics, including engineered target strains, exhibit therapeutic potential for correcting dysbiosis (Mills et al., 2019). Traditional fiber-rich and fermented diets also play an important role in supporting gut microbiota. Nevertheless, these approaches cannot replace direct ecological contact and should be regarded as complementary measures.

Despite existing progress, significant knowledge gaps remain. Further research is required to elucidate the mechanisms of microbial transmission from air and soil to the gut. Longitudinal studies tracking microbial exposure throughout the lifespan will help clarify the impact of early ecological deprivation on immune development. Additionally, the effects of climate change on microbial ecosystems and their relationship with human health require thorough investigation.

Conclusion

The interaction between environmental microbiota and the human gut microbiota represents a fundamental ecological and biological process that determines health status. Urbanization and modern lifestyles disrupt these ecological connections, leading to reduced microbial diversity and an increased risk of immune, metabolic, and allergic diseases. Measures such as urban greening, improved dietary habits, and the application of modern probiotic technologies offer promising pathways to compensate for these disruptions. Further interdisciplinary research is essential for developing sustainable strategies to preserve microbial ecosystems and strengthen population health.

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