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1 Microbiomes and Its Significance with the Current Applications in Human Health and Disease: Goals and Challenges of Microbiome Research Today

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Abstract

Human beings are home to a massive invisible microbial community, which powers nearly all processes in the body. Bacteria, archaea, viruses, protozoa, and fungi are the most common organisms in or on our bodies. These fascinating microbial species are called our microbiota collectively. The human body includes a wide number of bacteria, both inside and outside. In particular, it is the microbial genome set that leads to an overall human genetic picture. We know very little about how the pendulum between health and illness swings in our microbiome. The diversity and balance of our microbiome and vulnerability to diseases are inextricably linked. Here, we try to consolidate our existing knowledge about microbiome evolution and ecology in future studies, as well as to consider the relationships between host microbiomes and human health and disease. Finally, we highlight modern methods and technology to human health advancement. The present book on microbiomes is therefore intended to give readers a broad understanding and encouragement for future research and multidisciplinary cooperation on the goals and challenges of microbiome research today.

Keywords

Microbial communities · Microbiome’s diversity · Microbiomes · Human health

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1.1 Introduction

The set of microbiomes inside and within the human body can be classified as microbiome items. Scientists begin to recognize that microbes play a significant role in our human health. A standard microbiome has ten times as many cells as humans. Indeed, our body is a complex microbial ecosystem; a broad variety of bacteria, fungi, viruses, and microeucaryotes is contained here. The unique microbial combination that exists at each level and we sound like we have created a very significant and precise task along with our microbial partners in every niche. The human microbiome makes up more than 50% and it can influence our mood, appetites, and immune responses to a range of biological functions. Human beings host a huge invisible microbial environment, which affects almost every system of the body. Bacteria, archaea, viruses, protozoa, and fungi are the most common microbes that live within or on our bodies. This fascinating microbial group is known as our microbiota collectively.

1.2 The Complexity of the Microbiomes

The abundance and complexity of the microbiome are staggering with more than one million genes versus 23,000 in the human genome; microbiome communities have unique profiles in different body sites, as do each organism, affected by diet, medications, and other environmental factors (Coyte et al. 2021). The overwhelming proliferation of microbial organisms means that a supra-organism is the human body. Microbiomes are not microorganisms living alongside each other, but instead, form highly regulated complex structurally and functionally organized communities attached to the surfaces as biofilms that contribute to their ecological stability through interspecies and interspecies collaboration. Disease prevention is not the future, but health is the future, free of essential diseases (Shanahan et al. 2021). Multifaceted illness like autoimmune disorders, the human body is an extremely complex system in humans. It is getting more and more difficult to find medications today. It is time to alter the paradigm shift so that scientists across the globe begin focusing on the common theme that microbiomes in combinations of virus bacteria fungi and bacteriophage are related to any disease. In the microbes that we bring, we are each unique, yet they reflect another molecular fingerprint present in each individual. We deal with good and poor microbes in such a way that we know about dental caries caused by bacteria in the mouth, aches, or body odor in the skin and now we have a chance to interact with good bacteria. What these microbial species are doing within the human body is a fascinating issue, and there is a simpler way to cope with tooth cavities, aches, and digestive disorders to treat more serious health problems such as obesity, type 2 diabetes, irritable bowel syndrome, and depression. Given the pros and cons, we need to naturally achieve better health by using microbes that have co-evolved with us.

Otherwise, the human microbiome could be referred to as an undiscovered world that gets benefited in many respects viz. (a) Synthesizes and excretes vitamins

Vitamin B12 and Vitamin K. (b) Prevents contaminants that are difficult for attachment sites or essential nutrients. (c) From colonizing. Could probably alienate in the production of substances that inhibit or destroy nonindigenous species with other bacteria (nonspecific fatty acids, peroxides, bacteriocins). (d) Stimulate the growth of certain tissues, such as intestines, lymphatic tissues, capillary density. (e) The production of cross-reactive antibodies is enkindled. In addition to the ability to extract nutrients, microbiomes generate extra energy that is otherwise unavailable to the host, produce vitamins, metabolize trivial xenobiotics, and provide resistance to cancer and tumor-causing neoplasms, and help grow a mature immune system (Parida and Sharma 2021). Instead of researching the relationship between the microbiota, health, and disease, several studies have shown a connection between various microbial consortia and certain disease states; however, there is still little evidence that a specific disease is triggered by some sophisticated microbial group. The quest was subjugated by the early history of microbiology to discover the microbes responsible for disease and uncover ways to impede them. The first step in setting up ways to prevent and cure infectious diseases was the discovery and analysis of causative agents (Honda and Littman 2012).

1.3 Co-Evolution of Microbiomes with Humans

It looks like we have co-evolved with our microbial partners with very critical and complex tasks that exist in any given section. We are each special in the microbes we bear, but in each individual, they constitute another molecular fingerprint (Hooks and O'Malley 2020). Without any exception, we may map the microbes on the fingerprints and microbes on the machine keyboards to map the keyboard owner and verify how special these microbial signatories are. Microbiome habitats with high diversity are more robust and more resistant and able to return to their safe state of perturbation. We know that over the past few decades, there has been a rising prevalence of allergies, hypersensitivity disorders, and asthma in children. Changes in eating patterns, access to packaged food, decreased interaction with the natural world, the usage of antibacterial soaps, and the possibility of cleansers living in a sterile environment should be taught.

Unfortunately, we have pushed the development of our microbial species to a less complex and inherently less secure condition. Strikingly, microbiota modifications are known to be associated with different diseases, i.e., diabetes, obesity, cardiovascular diseases, carcinogenesis, host anatomy, metabolism, irritable bowel syndrome, and immune dysfunction (Tang et al. 2017). An increasing body of evidence indicates a strong correlation with changes in various disease states in microbiomes. To decipher the deeper understanding of the interactions of microbe disease, multiple studies are ongoing. This poses the exhilarating possibilities that we might think of different therapeutic goals if illnesses are correlated with changes in microbiota and begin to consider ways to transition back to a healthier state.

In multiple environments, microbiomes live and display remarkable differences within and between individuals. With different health states and phenotypes, variability is associated. In several roles, the microbiome is involved viz. production of vitamins, metabolic rate, digestion, odor, behavior, parasite or pathogen defense and Immune Regulation (Costello et al. 2009). Nevertheless, within the human body, hundreds of beneficial microbes reside and are critically important for sustaining human health. They are very functional in educating our immune system in the early years of life to identify them like themselves, but not themselves. They harvest energy from all of the food sources we consume in the (Gastrointestinal) GI Tract. Strikingly, we do not break down all the polysaccharides that we consume, for example. In the gut, microbes develop synthetic vitamins, metabolites, nourish the cells that line the GI tract, and most likely in all environments in the human body.

Researchers are now exploring circumspectly what our microbial inhabitants are doing and how they are contributing to or defending against disease. Research on microbiomes is evolving pretty rapidly to test how we see ourselves as humans. The body harbors at least as many microbial cells as human cells, and there are more than a million genes in our microbial gene database. Nevertheless, we still know very little about the function of most of the second genome and how it affects human health. Besides, microbiome types preserve innate immunity and adaptive immunity by building up the host's metabolic capacity to digest plant carbohydrates, milk products (glycans), vitamin endowments (e.g., B2, B12, K, and folic acid), protect against pathogenic bacteria colonization, and create resistance to colonization (Thaiss et al. 2016). Microbiota metagenome may also function with rapid modification of various strains, exchange of genetic elements, and occurrence of mutations in response to multiple environmental stimuli. The following variables have a vital effect on the microbiota (Nayfach et al. 2019). Host biology, individual lifestyle, diseases, antibiotic exposure, at-time colonization, and birth delivery type, respectively.

1.4 Microbiome Dysbiosis

The proliferation of our beneficial thriving microbes holds in check the pathogenic microbes and maintains a harmonious equilibrium. However, this equilibrium is disrupted when pathogenic microbes govern and we reach a state of dysbiosis. Dysbiosis of the microbiome has been associated with a large number of health problems and is causally concerned with metabolic, immunological, and developmental disorders, as well as susceptibility to the development of infectious diseases. Several illnesses, including cancer, inflammatory bowel disease, obesity, and asthma, are associated with dysbiosis. The composition of the microbiome can be affected by our lifestyle choices, our diet, our use of antibiotics and drugs, and the climate in which we live.

Microbiome dysbiosis has been associated with surplus health problems and has been associated with metabolic, immunological, and developmental disorders as well as susceptibility to infectious disease growth. Genetic and environmental factors causing impaired barrier function, overgrowth of pathogenic bacteria, and subsequent inhibition of defensive bacteria are proposed mechanisms that lead to dysbiosis. Translocation of bacteria and bacterial products into cells, immune activation and development of proinflammatory cytokines, chronic inflammation, the leaky gut term, leads to tissue destruction and complications. In the human body, the gut comprises the largest, densest, and most diverse microbial group. As a crucial determinant of nutrient uptake, energy regulation, and eventually, weight gain and metabolic disorders, recent research has also implicated the gut microbiota. In the future, gut flora modulation could be an important part of weight loss services and various therapies for illnesses. Some metabolites processed by gut microbes that drive the progression of many cardiovascular pathologies, such as atherosclerosis, hypertension, heart failure, and type 2 diabetes, have recently been identified by researchers (Lee and Hase 2014). "These findings suggest that by generating bioactive metabolites that can directly or indirectly affect host physiology, the gut microbiome functions like an endocrine organ" (Tang et al. 2019). Besides, in cancer development affecting predisposing conditions, particularly initiation, progression, response to therapy, microbiota also plays an imperative role (Matson et al. 2021).

The complexity of the fecal microbiota is actively being established and recent studies have shown that microbiota-related dysregulation results in the pathogenesis of several diseases. In the future, gut flora modulation could be an important part of weight loss services and various therapies for illnesses. A healthy intestinal microbiota is restored by fecal microbiota transplantation (FMT) and results in remarkable cure rates for many diseases and is likely to achieve widespread therapeutic advantage for several diseases in the future (Kelly et al. 2021). To work at the petri dish, genomics, and clinical results stage, such studies need translational science.

1.5 Significance of Microbiome Research.

The considerable quantity of research on the microbiome has led to a better understanding of the microbiome and its function in the human, urban, and natural environments in recent years (Cullen et al. 2020). Host-microbe studies such as interactions between the gut and diet offer a major insight into how the microbiome reacts over time to the introduction of new microbes and changes and may potentially serve as the roadmap for microbiome-based intervention and diagnostic technology.

The future microbiome diagnostics and therapeutics armamentarium provide broad and deep possibilities for the monitoring and treatment of a range of diseases-personalized diets, prebiotics, postbiotics, microbiota transplantation, engineered bacteriophages, microbial metabolites, precision editing of microbiota, and modulation of the intestinal barrier. Great data from such microbiome populations have led to the advent of computational genomics that helps to explore the enduring uncultured microbes attributable to current developments in metagenomic sequencing technologies and other omics platforms. Microbiome research has been catapulted into an exciting new frontier in medicine and human health by enormous developments in next-generation sequencing and Omics technologies. Promising knowledge indicates that the microbiome, the rich ecosystem of more than 100 trillion bacteria, fungi, and viruses in and on the human body, is important to all aspects of human health and disease, and that 1 day microbiome analysis may play an imperative role in clinical practice.

In recent years, microbiome research has improved noticeably, powered by developments in technology and a substantial reduction in study costs. Such research has unlocked a wealth of data that has provided significant insight into the existence of microbial communities, including their interactions and consequences, both as part of an ecological community within a host and in an external environment. Understanding the function of microbiota, including its complex interactions with its hosts and other microbes, will make it easier for new diagnostic techniques and interventional methods to be established that can be used in a variety of fields, from ecology and agriculture to medicine and forensics to exobiology.

It would also be very amazing to understand what microbes harbor each tissue and organ, what they encode, what they create as communication signals and how they transform over time, and how human health could be advanced by manipulating these signals. In order to facilitate tailored preventive and therapeutic approaches, systematic understanding and application of microbiome heterogeneity hold great promise. Increasing our experience in this area will afford proof of concept and implement new therapeutic pathways. The ultimate objective should facilitate to reinstate the status quo, using probiotics to replace vital missing and/or extinct microbiome species and strains that respond to essential developmental pathways, likely with accompanying prebiotics.

1.6 The Way Forward

To decide whether there are sets of microbes common to each person, several challenges are still underway. To learn whether modifications to our microbiota result in various health or disease states. New technologies for the study of complex microbial systems and the study of complex microbial systems within their natural environments should be developed (Carr et al. 2020; Galloway-Peña and Hanson 2020). Therefore, therapeutically targeting the makeup of the microbiota will put forward new methods for disease prevention and treatment. The unidentified taxa of bacteria and the analogous genetic levels at which they function are still the greatest impediment. For the next scientific frontier of human health that needs a lot of study, this may be resolutely indispensable (Liu et al. 2020). In addition, the convergence of multiple scientific disciplines and the use of innovative technical methodologies in microbiome research are expected to pave the way for the conception of evidence-based clinical treatments for the health problems of modern life (Methé et al. 2012; New and Brito 2020).

An overview of how the microbiome contributes to human health and illness is given in the book. The microbiome has also become a flourishing field of medical, agricultural, and environmental study. Readers can gain in-depth knowledge of the connection between microbiota, medicine, agriculture, and the environment, and immune defense systems. A number of researchers, physicians, and scholars working in biomedicine, microbiology, and immunology will be discussed in the book. There is no question that the execution of emerging technologies has revolutionized research initiatives by bringing new insights into the complexities of these complex microbial communities and their role in the fields of medicine, agriculture, and the environment. Centered on a wide variety of discipline principles and model systems, this book mainly offers a conceptual outline for understanding these interactions between human microbes, animal microbes, and plant microbes, while flaking fundamental light on the scientific challenges ahead. In addition, this book discusses why microbiome study warrants the opportunity to combine microbiology with human, animal, and plant physiology, evolutionary perspectives with metabolic science, ecological theory with immunology, and innovative and interdisciplinary thought (Berg et al. 2020).

This book offers an accessible and definitive guide to microbiome science's fundamental concepts, an exciting and rapidly evolving new field that transforms many aspects of life sciences. From thermal tolerance to diet in a typical immune system, these microbial partners can also drive ecologically essential traits and have led to animal diversification over long evolutionary timescales. This book also discusses why microbiome research offers a more comprehensive image of human and other animal biology, and how it can produce innovative human health treatments and new strategies.

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Conflict of Interest The author declares that they have no competing interests.

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