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Mini Review

Interactions of Nanotechnology and Human Microbiome

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Abstract

The human microbiome has long been recognized as playing critical roles in human health and disease. Nanotechnology interacts with the human microbiome. Human exposure to engineered nanomaterials is extensive in the modern world. However, our understanding of the effect of nanotechnology on human microbiome is limited. It is of public concern. Therefore, the impact of nanotechnology on human microbiomes is a new developing area of research. This review indicates that more studies are required using current and new technologies to develop a better understanding of the role the microbiome plays in human health.

Keywords: Microbiome; Microbiota; Human microbiome; Nanotechnology; Engineered nanomaterials; Human health

Introduction

The concept of the human microbiome and microbiome research is a 21st century scientific frontier. The word 'microbiome' was coined in 2001 when Lederberg and McCray1 published their monumental paper. They defined the human "microbiome" as "the ecological community of commensal, symbiotic, and pathogenic microorganisms that literally share our body space" [1].

Turnbaugh et al. [2] defined the microbiome as "the collection of the microorganisms and their genetic material in a particular environment". However, Prescott [3] argued that the microbiome was discovered much earlier in 1988 by Whipps et al. [4] defined as "A convenient ecological framework in which to examine biocontrol systems as that of the microbiome. This may be defined as a characteristic microbial community occupying a reasonably well defined habitat which has distinct physio-chemical properties. The term thus not only refers to the microorganisms involved but also encompasses their theatre of activity" [4].

A healthy human body carries millions of microorganisms. Together these organisms form a system called the microbiome [5]. The genomes that constitute the human microbiome represent a diverse array of organisms that includes bacteria, archaea, fungi, protozoans, and nonliving viruses, residing mostly in the gastrointestinal tract. Bacteria are the most numerous members of the human microbiome. The microbial imbalance suggests that the human body is a collection of human and microbial cells and genes and thus a blend of human and microbial traits. The diversity of the human gut microbiome increases from birth through childhood and remains relatively stable during adult life and then begins to decline with age [6].

The interest of the biomedical community in the human microbiome has increased dramatically in recent years. The microbiome is a dynamic living system. It is affected by changes in its environment. When the normal environment of a microbiome is disturbed by external factors, potentially harmful adverse health effects can occur. Environmental factors such as diet, new microbes, medication or antibiotics, foreign chemicals, and infection, have been shown to alter the microbiome, potentially leading to a pro-inflammatory state. Antibiotics severely affect the human gut microbiome creating an imbalance including increased numbers of antibiotic-resistant bacteria. Such chronic alterations in the human gut play a major role in the development of adverse health effects. Recent studies have identified potential agents that can protect the human gut microbiome from such adverse health effects caused by antibiotic treatment, supporting the important observation that microbes play an important role in human health and disease. The dysfunction of the microbiome is associated with obesity, diabetes, liver and renal diseases, cancer, and cardiovascular diseases [6].

Knowledge of the human microbiome expanded rapidly in recent years. The decreasing cost of whole-genome sequencing technology, the process of comparing DNA sequences of microorganisms isolated from different parts of the human body and different people has increased. As a result, nearly 200 different bacterial species of the human microbiota have been characterized. The benefits of microbiome are many and diverse. The impact of human microbiome research on human health and disease is of public interest. The interaction between the diet, and the microbiome and their effect on the host organism is an important and expanding area of research. This rapidly developing area of research has attracted worldwide attention. In a time frame of approximately the last two decades, microbiome research has seen remarkable growth. This review presents some of its history and reflects on the future of the human microbiome.

Human Microbiome and Nanotechnology Interactions

With advancement of nanotechnology studies have shown that nanoparticles have anti-bacterial properties. Zinc oxide nanoparticles have antibacterial properties [7,8]. Silver nanoparticles have similar properties [9]. These studies have demonstrated that nanotechnology can be used for treating bacterial infections. Human microbiome plays a critical role in the development of human diseases such as cancer [5]

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and, therefore, it appears that there is an interaction between human microbiome and nanotechnology.

Microbiome and Human Environment

Diet and environmental chemicals such as bisphenols, phthalates, heavy metals, and pesticides can significantly alter the human gut microbiome [5]. Interactions of human microbiome and host metabolism is associated with human disease and toxicity, and more than likely play a role in nonclinical testing of drug candidates [5].

Human Microbiome and Human Disease

With advancement of nanotechnology the nanomaterials were used to treat human diseases [10]. Nanomedicine is a growing new developing area of nanotechnology. It will lead to major advances in diagnosis and treatment of diseases including cancer such as colorectal cancer where gut microbiomes may play significant roles in cancer development and treatment. Nanotechnology has been used for cancer diagnosis and treatment. Interactions of microbiome, nanotechnology and the tumor microenvironment have led to treatment of cancer [11]. Bacteria in human colon are associated with the development of colorectal cancer [12]. Change in the composition of gut bacteria leads to altered gut microbiome inducing colorectal cancer.

Human Microbiome and Host Metabolism

Recent studies suggest a critical relationship between the human microbiome and host metabolism [5]. The interactions of the microbiome and host metabolism play a critical role in human health and disease. Changes in human microbiome affect human health leading to disease conditions. Microbiome development is affected by environmental factors. Diet and environment significantly alter the human microbiome. Metabolism of environmental chemicals by enzymes from the host's microbiota affects the toxicity of that chemical to the host. Such interactions between the human microbiome and host metabolism appear to be an important factor associated with human disease and toxicity, and more than likely play a role in nonclinical testing of drug candidates.

Conclusions and Future of Human Microbiome Research

Our current understanding of the human microbiome, which plays an important role in human health and disease, is limited. Significant progress has been made in recent years, but there is more information we don't know. Imbalance in human microbiota leads to adverse health effects such as inflammatory bowel disease, colorectal cancer and diabetes. Human microbiome continues to present significant challenges for understanding all aspects of its interactions and their implications. These issues and knowledge gaps need to be addressed. More studies are required using up-to-date technologies and highlighting its future directions. Clinical applications of human microbiome are evolving. A few clinical applications such as fecal transplantation are used currently. However, more such applications are expected to be discovered. This review indicates that more studies are required using current and new technologies to develop a greater understanding of the role the human microbiome plays in human health and disease and drug development.

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