

Gut Feelings: Unravelling the Secrets of the Microbial Universe Within

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Abstract

The human digestive system hosts a varied and dynamic community of microorganisms, commonly known as the gut microbiota. This complex community, which includes various organisms such as bacteria, archaea, viruses, and fungi, is essential and important for numerous bodily functions such as metabolism, immune response, and cognitive development. The composition and vast diversity of the gut microbiome are shaped by diet, lifestyle, and genetic factors. Disruptions in this balance, known as dysbiosis, have been associated with various health issues, including obesity, inflammatory bowel diseases, and metabolic disorders. Recent breakthroughs in molecular technologies, such as metagenomics and metabolomics, have allowed scientists to unravel the intricate composition and functions of the gut microbiome, offering new insights into its influence and effect on human health and various diseases. Beyond digestion and nutrient absorption, the gut microbiome plays key roles in immune system regulation, maintaining gut barrier integrity, and supporting overall bodily balance. Therapeutic strategies designed to alter the gut microbiome, such as probiotics, prebiotics, and fecal microbiota transplants, have shown promise in addressing a range of health issues. Additionally, growing research indicates that yoga may benefit gut health by reducing stress, enhancing digestion, and supporting microbial balance. Future studies will likely focus on developing microbiome-based diagnostics, personalized treatments, and innovative therapies such as postbiotics, phage therapy, and engineered microbiota. By deepening the understanding of interactions between both the gut microbiome and human health, new opportunities for diagnosis, prognosis, and targeted therapies can emerge, transforming healthcare in the process.

Keywords: Gut microbiome, gut composition, diagnosis, dietary intervention, yoga practices, human health

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Received Date: September 13, 2024

Accepted Date: October 15, 2024

Published Date: November 15, 2024

Citation: Yashashwi Shrivastav, Sanika Balekar, Neelam Balekar. Gut Feelings: Unravelling the Secrets of the Microbial Universe Within. Research & Reviews: A Journal of Immunology. 2024; 14(3): 21–33p.

INTRODUCTION

The human gut hosts a very vast, diverse and dynamic community of microorganisms which collectively referred to as gut microbiota. These micro-organisms play a vital role in human health by contributing to physiological processes such as metabolism, immune regulation, and cognitive development [1, 2].

The gut microbiome, which consists of trillions of tiny organisms, including bacteria, archaea, fungi, and viruses, has become a significant area of scientific inquiry due to its critical influence on both health and disease. It plays key roles in digestion, nutrient metabolism, immune system maturation, and even neurological functions. As research delves deeper into the gut composition, diversity, and functionality, it's becoming clear that this area

holds great potential for advancing diagnostics, prognostics, and targeted therapeutic interventions. One crucial aspect of the gut microbiome is its sensitivity to dietary influences [3].

The composition and activity of the gut microbiota can be greatly affected by different dietary elements, especially proteins. Disruptions in this microbial community, referred to as dysbiosis, have been linked to numerous health related issues which includes obesity, inflammatory bowel disease (IBD), and metabolism related disorders. However, the precise impact of high-protein diets on the gut microbiome remains unclear, highlighting the need for further exploration. Advances in molecular tools such as metagenomics and metabolomics have dramatically improved understanding of gut microbiome [4].

Recent studies have underscored the significant role of gut microbiota in overall human health, with imbalances in this system being implicated in a wide range of disorders, from gastrointestinal problems to neurological conditions. The gut microbiome, which includes the genetic material of the gut microbiota, contains approximately 150 times more genes than human genome, illustrating its complexity and significance [5].

These advanced technologies have allowed researchers to decode the intricate composition of gut and functions of microbiome, providing new insights into its contributions to human health and disease.

GUT MICROBIOME

The phrase “gut microbiome” describes the combined genetic material of all microorganisms living in the human gastrointestinal tract. This microbiome is essential for various physiological processes, such as digestion and nutrient absorption. The microorganisms in the gut can extract nutrients from substrates that the human body cannot digest, such as xyloglucans found in certain vegetables. Furthermore, the gut microbiome is responsible for producing Short-Chain Fatty Acids (SCFAs) from indigestible fibers, which serve as an energy source for the intestinal lining and influence immune responses and gut-related cancer development. Additionally, gut microbiome interacts with host's immune system, helping to train it to function effectively [6].

The microorganisms in the gut, including bacteria, archaea, viruses, and eukaryotic organisms, are vital for sustaining overall health and balance in the body. Often referred to as a “forgotten organ” due to its vast and diverse microbial population, the gut is crucial for processes such as digestion, nutrient absorption and distribution, immune system development, and even neurological health [7, 8].

COMPOSITION AND DIVERSITY OF THE GUT MICROBIOME

The makeup and variety of microbiome can differ greatly from person to person individually, influenced by different factors such as dietary habits, lifestyle choices, genetics, and environmental factors. While the core microbiome, comprising the most abundant and ubiquitous microbial species, remains relatively stable within an individual, the overall microbial community can be highly dynamic and responsive to changes in the host's internal and external environments (Figure 1) [9].

The intestinal microbiota is integral to the human health, playing key roles in the nutrient digestion, immune regulation, and the pathogen defence. This diverse microbial community ferments dietary fibers, produces essential vitamins, and metabolizes bile acids while modulating the immune system through interactions with gut-associated lymphoid tissue, promoting immune cell development, and maintaining gut barrier integrity. Additionally, the microbiota protects against pathogens via competitive exclusion, antimicrobial compound production, and immune response stimulation. The symbiotic relationship between the host and its microbiota is essential for homeostasis. Dysbiosis, which refers to imbalance in microbial community of gut, can interfere with normal physiological processes and contribute to gastrointestinal issues such as inflammatory bowel disease and irritable bowel syndrome. It is also associated with systemic conditions like obesity, diabetes, and various

neurological disorders. Therefore, ensuring a balanced gut microbiota is must for maintaining overall human health and preventing disease [10].

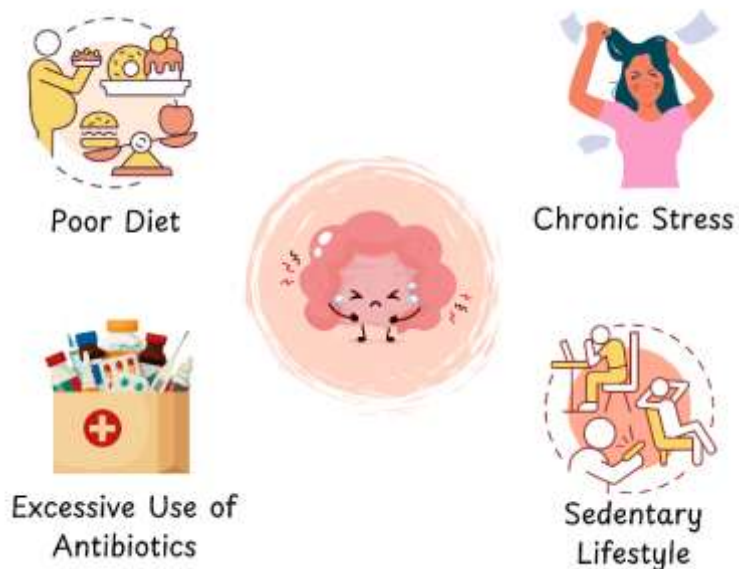


Figure 1. Factors leads to bad gut health.

Methods for Analysing Microbiome Composition

Analysing the composition of the gut and its microbiome involves various advanced techniques that provide insights into microbial diversity, abundance, and function. Here are the primary methods used:

- *16S rRNA gene sequencing*: This method amplifies and sequences the 16S ribosomal RNA gene, a highly conserved region in bacteria, to identify and compare microbial communities. It provides taxonomic resolution at the genus level. Cost-effective, widely used, suitable for large-scale studies. Limited to bacteria and archaea, lower resolution compared to whole-genome sequencing [11, 12].
- *Metagenomic sequencing*: This method sequences the entire genomic content of a sample, offering insights into both the functional capabilities of the microbiome and its taxonomic makeup. High resolution includes bacteria, archaea, viruses, and eukaryotes, offers insights into metabolic pathways. Disadvantages: More expensive and computationally intensive than 16S rRNA sequencing [13, 14].
- *Shotgun metagenomics*: Like metagenomic sequencing, this method randomly sequences DNA fragments from all organisms present in the sample, allowing for the reconstruction of microbial genomes and functional analysis. Advantages: Provides detailed taxonomic and functional profiles, high resolution. Disadvantages: High cost requires significant computational resources [15, 16].
- *Meta transcriptomics*: This method sequences the RNA transcripts in a sample, offering a snapshot of active microbial functions and gene expression. Advantages: Reveals active metabolic pathways and microbial activity, not just potential. Disadvantages: RNA is less stable than DNA, making sample collection and storage more challenging [17].
- *Metaproteomics*: This technique analyses the proteins expressed by the microbiome, providing insights into microbial functions and interactions. Advantages: Direct measure of functional activity identifies proteins and their modifications. Disadvantages: Technically challenging, requires sophisticated instrumentation [18].
- *Metabolomics*: This method profiles the metabolites produced by the microbiome, giving a comprehensive view of the chemical activities within the gut ecosystem. Advantages: Provides functional insights, links microbial activity to host metabolism. Disadvantages: Metabolite identification can be complex, requires advanced analytical techniques [19].

- *Single-cell genomics*: This innovative technique entails isolating and sequencing the genomes of individual microbial cells, offering detailed insights into the genetic diversity of the microbiome. Advantages: High-resolution, captures rare and unculturable microbes. Disadvantages: Technically complex, requires specialized equipment and expertise [20].

By employing these diverse techniques, researchers can find and gain a comprehensive knowledge of gut and its composition, functions, and interactions in gut microbiome, driving advancements in health and disease research.

FUNCTIONAL ROLES OF THE GUT MICROBIOME

Metabolic Functions

The human gut microbiome plays a vital role in the host's metabolic processes, contributing to digestion, vitamin production, and the creation of short-chain fatty acids (SCFAs).

- *Digestion*: The microbiome helps break down complex carbohydrates, proteins, and fats that human enzymes cannot digest on their own, facilitating more efficient nutrient absorption. [21].
- *Vitamin synthesis*: Gut bacteria also produce essential vitamins, including vitamin K and B vitamins like B12, riboflavin, folate, and biotin, which are critical for both metabolic and neurological functions [22].
- *Short-chain fatty acid production*: Additionally, fermentation of the dietary fibers by gut microbes gives the formation of SCFAs, such as acetate, propionate, and butyrate. These short-chain fatty acids (SCFAs) are crucial for providing energy to colonocytes, regulating inflammation, and preserving the integrity of the gut barrier. SCFAs also play a role in systemic health by influencing metabolic and immune responses [23].

Immune System Modulation and Gut Barrier Integrity

The gut plays a key role in shaping the host's immune system and supporting the integrity of the gut barrier and microbiome.

- *Immune system modulation*: Microbial components and metabolites, such as short-chain fatty acids (SCFAs) and peptidoglycan, interact with immune cells to regulate immune responses, which is essential for developing a well-balanced immune system and reducing the risk of autoimmune diseases [24].
- *Gut barrier integrity*: Additionally, gut contributes to maintaining intestinal epithelial barrier by regulating production of tight junction proteins and mucus. This barrier function is essential for preventing pathogen invasion and systemic inflammation [25].

Role in Maintaining Homeostasis and Health

The gut and its microbiome play crucial role in balancing and maintaining overall health and homeostasis by regulating a variety of physiological processes.

- *Metabolic homeostasis*: Microbiome's role in metabolizing dietary components and producing bioactive metabolites helps regulate host energy balance and metabolic health [26].
- *Neurological health*: Gut-brain axis emphasizes the impact of gut on neurological functionality and mental well-being. Microbial metabolites like SCFAs and neurotransmitter precursors can affect brain function and behavior [27].
- *Disease prevention*: A balanced gut microbiome is protective against various diseases, including gastrointestinal disorders (e.g., inflammatory bowel disease), metabolic syndromes (e.g. obesity, type 2 diabetes), and even cardiovascular diseases.

Gut microbiome carries out essential metabolic functions, regulates the immune system and gut barrier integrity, and is fundamental in sustaining overall health and homeostasis. Advances in understanding these functions can lead to novel therapeutic strategies for various diseases.

GUT MICROBIOME AND HOST HEALTH

The gut microbiome of human body plays a vital role in balancing host health and overall homeostasis. An imbalance in gut microbial community is called as dysbiosis, has been linked to

various health conditions, including inflammatory bowel diseases, metabolic disorders, autoimmune diseases, and neurological disorders [8, 9].

Impact on Digestive Health

Gut microbiome is essential for digestive health and is associated with several gastrointestinal conditions such as irritable bowel syndrome (IBS) and inflammatory bowel disease (IBD).

- *Irritable Bowel Syndrome (IBS)*: It is marked by symptoms such as abdominal pain, bloating, and alterations in bowel habits. Studies indicate that dysbiosis, or an imbalance of gut microorganisms, is commonly found in individuals with IBS. This disruption in the microbiome can enhance gut permeability, trigger immune responses, and modify communication between the gut and brain, all of which play a role in IBS symptoms [28].
- *Inflammatory Bowel Disease (IBD)*: It encompasses conditions such as Crohn's disease and ulcerative colitis, both of which involve long-term inflammation of the gastrointestinal tract. Studies had demonstrated that IBD individuals experience reduced microbial diversity and imbalance between both, pro-inflammatory and anti-inflammatory bacteria. These microbial alterations can exacerbate intestinal inflammation and affect the gut barrier function [29].

Connections to Metabolic Disorders

The microbiome of gut has been increasingly recognized for its significant role in metabolic health, affecting conditions like obesity and diabetes.

- *Obesity*: Gut composition differs significantly between an obese and the lean individuals. It is associated with increased capacity for energy harvest from diet and alterations in metabolic pathways. Specific bacterial strains can influence host metabolism, fat storage, and appetite regulation [30].
- *Diabetes*: Type 2 diabetes is associated with shifts in gut microbiota, including decreased microbial diversity and changes in specific microbial groups. These changes can affect glucose metabolism, insulin sensitivity, and inflammatory pathways, contributing to the pathophysiology of diabetes [31].

Influence on Mental Health and Neurological Conditions

Gut-brain axis refers to bidirectional communication system between human gut microbiota and brain, impacting both mental health and neurological conditions.

- *Gut-Brain Axis*: Microbial metabolites, such as SCFAs and neurotransmitters (e.g., serotonin, dopamine), can affect brain function and behavior. An imbalance in gut microbiota has been linked to mental health conditions, including depression, anxiety, and autism [32].
- *Neurological conditions*: Changes in the gut microbiome have also been linked to neurological disorders which includes Parkinson's and Alzheimer's diseases. Gut microbiota can influence neuroinflammation, amyloid-beta plaque formation, and neuronal health [33].

Relationship with Immune-Related Conditions

The microbiome plays a fundamental role in modulating the host's immune system and is implicated in immune-related disorders including allergies and autoimmune diseases.

- *Allergies*: An imbalance in gut during early development is linked to a heightened risk of allergy onset. Microbiota helps educate immune system, promoting tolerance to harmless antigens and preventing allergic responses [34].
- *Autoimmune diseases*: The gut and its microbiome influence the development of autoimmune disorders such as rheumatoid arthritis, multiple sclerosis, and type 1 diabetes. Dysbiosis can disrupt immune regulation, fostering autoimmune reactions and chronic inflammation [35].

By exploring the roles of the gut microbiome in these conditions, researchers can devise targeted treatments and strategies to restore or maintain microbial balance, thereby enhancing overall health outcomes.

THERAPEUTIC INTERVENTIONS TARGETING THE GUT MICROBIOME

Probiotics and Prebiotics: Mechanisms and Efficacy

- *Probiotics*: These are live micro-organisms that confer health benefits to host when consumed in appropriate and enough. Probiotics improve gut health by strengthening its barrier, regulating immune system, and suppressing harmful bacterial growth. Examples of common probiotic strains include *Lactobacillus*, *Bifidobacterium*, and *Saccharomyces*. They are beneficial in treating conditions like irritable bowel syndrome (IBS), antibiotic-associated diarrhea, and inflammatory bowel disease (IBD) by reestablishing microbial balance and improving gut function [36].
- *Prebiotics*: These are indigestible food components that specifically encourage the growth and activity of beneficial gut bacteria. Found in dietary fibers like inulin, fructo-oligosaccharides (FOS), and galacto-oligosaccharides (GOS), prebiotics serve as nourishment for beneficial microbes. This process leads to production of short-chain fatty acids (SCFAs), which offer several health advantages, including decreasing inflammation and supporting the integrity of the gut barrier (Figure 2) [36].

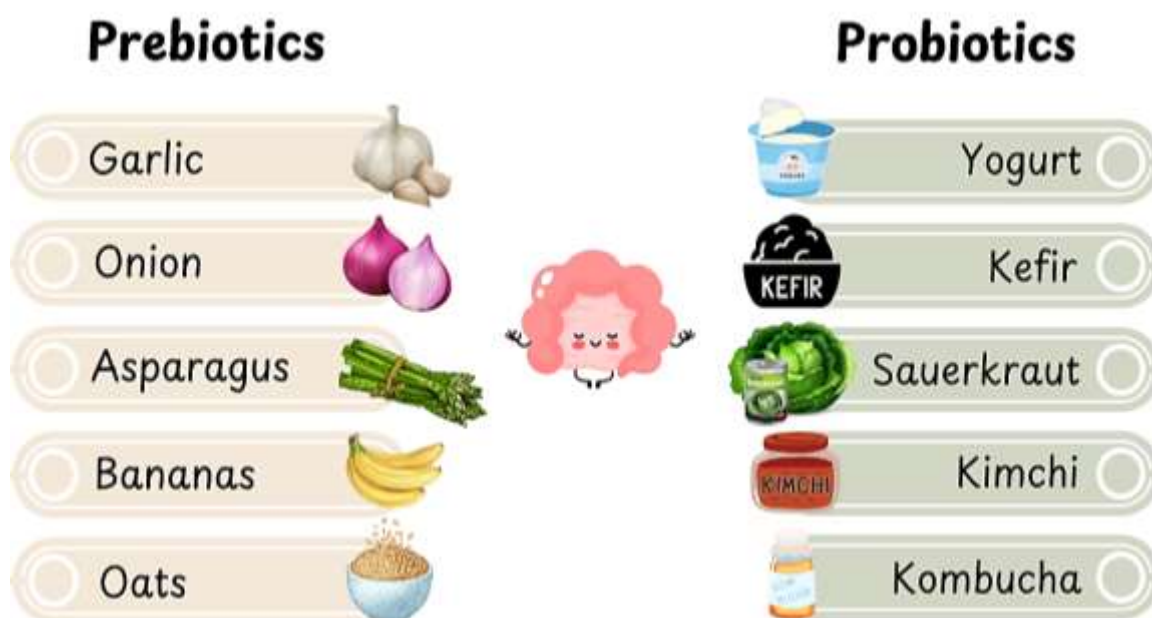


Figure 2. Foods for promoting gut health.

Dietary Interventions and Their Impact on the Microbiome

Dietary interventions are crucial in shaping the composition and function of the gut microbiome. Different types of diets can either promote microbial diversity and health or contribute to dysbiosis and disease.

- *High-fiber diets*: Consuming a diet abundant in fiber from sources like fruits, vegetables, whole grains, and legumes fosters the growth of bacteria that produce short-chain fatty acids (SCFAs). SCFAs are crucial for gut health, as they help reduce inflammation, support energy for colonocytes, and contribute to overall gut maintenance [37].
- *Polyphenol-rich foods*: Polyphenols, found in foods like berries, tea, coffee, and dark chocolate, are metabolized by gut bacteria into bioactive compounds with anti-inflammatory and antioxidant effects. These bioactive compounds can support gut health and help lower the risk of chronic diseases [37].
- *Fermented foods*: Eating fermented food such as yogurt, kefir, sauerkraut, and kimchi adds live beneficial bacteria to the gut. Regular intake of these fermented foods can enhance gut microbiota, improve immune response, and support general well-being (Figure 3) [37].



Figure 3. Examples of dietary intervention foods.

Influence of Yoga Practices on Gut Microbiome Health

Yoga, an ancient mind-body practice originating from India, has gained increasing attention among researchers and healthcare professionals for its potential benefits on gut health and overall well-being. Studies suggest that the various physical postures, breathing techniques, and meditative aspects of yoga may positively influence the gut microbiome, reduce inflammation, and promote digestive function [38].

Yoga can enhance gut microbiome health through several mechanisms, including stress reduction, improved digestive function, and better circulation. By lowering stress levels, yoga positively influences the gut-brain axis, which can lead to a more balanced gut microbiome. Specific yoga postures stimulate digestive organs, promoting better digestion and gut motility. Additionally, yoga helps regulate the autonomic nervous system, balancing the body's responses and supporting gut health. The practice also reduces inflammation, which can protect the gut lining and foster a healthier bacterial community. Furthermore, yoga often encourages healthier lifestyle choices, such as mindful eating and regular physical activity, all of which contribute to a more diverse and balanced gut microbiome.

The study investigated the impact of a 3-month yoga program on digestive health and sleep quality in older adults. A total of 96 participants, aged 60 to 75, who had not practiced yoga in the past year and had a Zubrod score of 0–2, were included. They were randomly divided into a yoga group (n = 48) and a waitlisted control group (n = 48). The yoga group participated in sessions three times weekly. To assess changes, the Pittsburgh Sleep Quality Index (PSQI) and the Patient Assessment of Constipation Quality of Life (PAC-QOL) were employed. Out of the original participants, 81 completed the study. Results indicated significant improvements in sleep quality and constipation-related quality of life for the yoga group compared to the control group, with most assessed parameters showing statistically significant differences. This suggests that yoga may effectively address issues related to constipation and sleep disturbances in the elderly, supporting its use as a beneficial practice for improving overall quality of life [39].

Additionally, research conducted by Isha Institute of Inner Sciences (McMinnville, TN) evaluated the effects of an advanced meditation program called Samyama, combined with a vegan diet high in raw foods, on the gut microbiome and metabolite profiles of 288 participants. Stool samples were analyzed at three stages: two months before the program (T1), immediately before starting (T2), and three months after completion (T3). While alpha diversity did not show significant changes between the meditators and the controls, beta diversity indicated significant shifts in microbiota of meditators post-Samyama ($p_{adj} = 0.001$). During the preparation phase, meditators had elevated levels of branched short-chain fatty acids, such as iso-valerate ($p_{adj} = 0.02$) and iso-butyrate ($p_{adj} = 0.019$) at T2. These results suggest that the combination of meditation and a vegan diet can positively alter gut bacteria, with these changes persisting three months after the program. The study underscores the need for further investigation to confirm these findings and to understand the mechanisms connecting diet, meditation, and gut microbiome changes with mental health outcomes like mood regulation (Figure 4) [40].



Figure 4. Yoga asanas for healthy Gut.

Fecal Microbiota Transplantation (FMT)

Fecal microbiota transplantation (FMT) involves transferring stool from a healthy donor into the gastrointestinal tract (GIT) of a recipient to restore a balanced microbial environment in the recipient's gut.

- *Procedures:* FMT can be administered through colonoscopy, enema, nasogastric tube, or oral capsules containing freeze-dried stool. Donor selection is critical, requiring rigorous screening to exclude infectious agents and other health risks [41].
- *Applications:* FMT has proven to be highly effective in managing recurrent *Clostridium difficile* infections (CDI), achieving success rates above 80%. Emerging evidence suggests potential benefits for other conditions, including IBD, IBS, metabolic syndrome, and neuropsychiatric disorders, though additional research is required to validate these potential advantages [41].

- *Outcomes:* Clinical trials have demonstrated the efficacy of fecal microbiota transplantation (FMT) in treating *Clostridium difficile* infection (CDI), resulting in long-term remission and improved quality of life for patients. The procedure is typically safe, with only mild and rare adverse effects [41].

Emerging Therapies and Future Directions

The field of gut microbiome research is advancing quickly, with several innovative therapies emerging:

- *Postbiotics:* These are non-living products or metabolic byproducts of probiotic microorganisms that offer health benefits. These include SCFAs, bacteriocins, and enzymes that modulate physiological processes and improve health outcomes [42].
- *Phage therapy:* This method utilizes bacteriophages – viruses that specifically target and kill certain bacteria – to influence the gut microbiome. Phage therapy offers a precision approach to targeting pathogenic bacteria without disrupting beneficial microbial communities [43].
- *Synthetic microbiota:* Scientists are developing synthetic microbial communities, comprising defined sets of microbial strains with known beneficial properties. These synthetic consortia aim to provide consistent and targeted therapeutic effects, offering potential for personalized medicine [44].

TECHNOLOGICAL ADVANCES IN MICROBIOME RESEARCH

High-Throughput Sequencing Technologies

These have significantly advanced microbiome research by providing a detailed and extensive analysis of microbial communities with exceptional depth and precision.

- *Next-generation sequencing (NGS):* NGS methods, such as those offered by Illumina, have transformed the field by enabling rapid and the cost-effective sequencing of entire microbial genomes. This technology has greatly enhanced our understanding of microbial diversity and composition across various environments, including the human gut. NGS platforms can perform metagenomic sequencing, which sequences all genetic material in a sample, allowing the identification and characterization of thousands of microbial species simultaneously [45].
- *Third-generation sequencing:* Technologies like Oxford Nanopore and PacBio SMRT sequencing offer long-read sequencing capabilities, providing more comprehensive genomic assemblies and insights into structural variations and complex regions of microbial genomes. These technologies also facilitate real-time sequencing, which is valuable for rapid microbiome analyses and diagnostics [46].

Metabolomics and Functional Assays

This field concentrates on the thorough examination of metabolites within biological systems, providing insights into the metabolic status and activities of microbial communities. It is essential for investigating the functional abilities of the microbiome and its interactions with the host.

- *Mass spectrometry (MS):* Mass spectrometry (MS)-based metabolomics plays a crucial role in identifying and quantifying a wide range of metabolites. Techniques like liquid chromatography-mass spectrometry (LC-MS) and gas chromatography-mass spectrometry (GC-MS) are widely utilized to analyze metabolites in microbiome research, offering valuable insights into microbial metabolism and its impact on host health [47].
- *Nuclear magnetic resonance (NMR) Spectroscopy:* The NMR spectroscopy provides detailed information of the structure and dynamics of metabolites. It is a powerful tool for metabolomics, offering high reproducibility and the ability to analyse a broad spectrum of metabolites without extensive sample preparation [48].
- *Functional assays:* Functional assays, including enzyme activity measurements and metabolic flux analysis, complement metabolomics by providing insights into the dynamic metabolic processes within microbial communities. These assays help in understanding how microbial metabolism affects host physiology and disease states [49].

Computational Tools and Bioinformatics Approaches

The incorporation of sophisticated computational tools and bioinformatics methods is crucial for analyzing and interpreting the large volumes of data produced by microbiome research.

- *Metagenomic data analysis:* The latest Tools such as QIIME (Quantitative Insights into Microbial Ecology) and Mothur facilitate the analysis of 16S rRNA gene sequences, enabling researchers to profile microbial communities, assess diversity, and identify taxa. For shotgun metagenomics, tools like MetaPhlAn and HUMAnN provide species-level taxonomic profiling and the functional potential of the microbial communities [50].
- *Metabolic pathway reconstruction:* Software like KEGG (Kyoto Encyclopaedia of Genes and Genomes) and Meta Cyc enables the reconstruction of metabolic pathways from metagenomic data. These platforms assist in analysing the functional roles of microbial communities and their influence on host metabolism [51].
- *Machine learning and AI:* The Machine learning algorithms and new advanced and latest artificial intelligence (AI) approaches are increasingly applied to microbiome data to identify patterns, predict health outcomes, and discover novel microbial interactions. These methods enhance the ability to interpret complex datasets and generate new hypotheses [52].

These technological advances have significantly expanded our understanding of the gut and its vast diversity of microbiome and its impact on health of human. As these tools continue to evolve, they will provide even deeper insights and more precise interventions for modulating the microbiome to improve health outcomes.

FUTURE PERSPECTIVES IN GUT MICROBIOME RESEARCH

Microbiome-based diagnostics and therapies hold vast potential in personalized medicine, paving the way for major progress in disease identification and treatment. These diagnostics can detect microbial patterns associated with conditions such as colorectal cancer and inflammatory bowel disease (IBD), enabling earlier diagnosis and tailored treatments. New therapies, including probiotics, prebiotics, symbiotic, and fecal microbiota transplantation (FMT), are designed to restore microbial balance and enhance personalized care. Future research should prioritize long-term studies to observe microbiome changes, explore the mechanisms behind microbiome-health relationships, and develop cutting-edge therapies like microbiome editing with CRISPR-Cas and synthetic biology. These innovations are set to transform healthcare by delivering more precise, personalized, and effective treatments.

CONCLUSIONS

The gut microbiome plays a vital role in sustaining digestive health, with its diversity shaped by factors like diet and lifestyle choices. Dietary approaches, such as incorporating fibre-rich foods and polyphenols, can help foster a healthy balance of gut bacteria. Moreover, yoga has been shown to positively impact gut health. Advances in microbiome-focused diagnostics are paving the way for personalized medicine by enabling the identification of microbial patterns associated with different health problems. These developments have the potential to revolutionize healthcare by providing more targeted and effective treatment options.

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