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Microbial Imbalance in the Gut: Implications for Obesity and Malnutrition

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Abstract

The global rise in obesity and malnutrition, including nutrient-deficiency disorders, raises ethical concerns about current development priorities. Children under five are especially affected, with consequences such as impaired bone growth and disruptions in early brain development, including neurogenesis and synaptogenesis. Responses from both individuals and institutions have been limited. While health awareness is increasing, lifestyle-based efforts often overlook the structural issues of food insecurity and nutrient availability. Government strategies have not sufficiently addressed the need for sustainable nutrition systems. Providing food alone is inadequate; the focus should be on restoring essential nutrients and supporting balanced diets. Recent studies highlight the gut microbiota as a key factor in human nutrition. These microbial communities, located in the gastrointestinal tract, live in a symbiotic relationship with the host. They have evolved to support the digestion of complex nutrients and influence multiple physiological processes. Research on the gut-brain axis has shown that microbiota play a significant role in health regulation. This review examines the relationship between gut microbiota and human biology, analyzes the effects of microbial symbiosis, and reviews interventions designed to address nutrient imbalances. Based on current findings, gut microbiota-targeted therapies offer a viable and cost-effective approach to reducing the impact of obesity and malnutrition.

Keywords: Gut Microbiota, Obesity, Malnutrition, Dysbiosis, SCFA, Therapeutic Interventions, Gut-Brain Axis, Microbiome Diversity, Fecal Microbiota Transplantation, Probiotics and Prebiotics

1. Introduction

In the year 2025, the halfway point of the 21st century, we have witnessed the emergence and decline of numerous diseases and infections, some lasting a few days while others for countless months. Among various health challenges, obesity has shown the most significant increase. According to the Health Topics of the WHO, it is estimated that in children, obesity has increased from 2% to 8% globally, while the percentage of adults has increased from 7% to 16%. The widespread prevalence is particularly concerning. According to WHO, it is estimated that in all the regions of the World, excluding South-East Asia, this issue is found in at least 10% of the population. According to WHO, in 2022, only 1 in 8 people in the world were living with obesity, with over 35 million children under 5 years old obese. One of the few illnesses/conditions for which a definite cure remains elusive. If the problem of Obesity wasn't enough, Malnutrition also represents a critical global health concern. According to WHO, 390 million people in the world are infected with this illness, 149 million of them being innocent children below the age of 5. The developmental, economic, social, and medical impacts of the global burden of malnutrition are serious and lasting, for individuals and their families, for communities, and for countries. In a general sense, Malnutrition refers to deficiencies, excesses, or imbalances in a person's intake of energy and/or nutrients. This definition might state the reason why many people are victims of this illness. Improper dietary intake and unbalanced food consumption are the secondary causes of this, while the primary reason is still the unavailability of all the dietary nutrients.
Addressing this persistent issue, which has shown no notable decline as of 2025, may necessitate novel and

unconventional approaches, which would be more formal. This brings us into the research on a new area of interest, the Gut Biome. The gut microbiome refers to the complex community of microorganisms, including bacteria, archaea, fungi, and viruses, that reside in the gastrointestinal tract of humans and other animals. Considered a beneficial evolutionary adaptation, it lives in a symbiotic relation with us, helping us digest food, break down tough proteins, and fight against infectious organisms to protect us. This field of microbiome was discovered quite late, in the 20th century, after many scientists wished to investigate the gut-brain axis, an understanding that the gut and the brain have a special connection that influences this research. Due to this, it is a proactive move to investigate the relationship between obesity, malnutrition, and gut microbiota. Preliminary research has shown that this relationship has significant potential. Thus, following repeated failure to reverse obesity and malnutrition with conventional measures, a research focus on the gut microbiota is a science- based, biologically plausible, and potentially game-changing strategy. Exploration of microbiota- mediated metabolic programming has the potential to be the key to maximally effective individualized nutrition and microbiome-targeted therapies, a route that may finally have the ability to begin to reverse the direction of these modern epidemics of disease.

In this article, we delve into the intricate relationship between gut microbiota, obesity, and malnutrition, aiming to uncover how this microbial ecosystem may hold the key to managing and possibly reversing these pressing global health challenges. We explore how the gut microbiome influences nutrient absorption, energy balance, and metabolic health, and how its composition varies in individuals affected by obesity or malnutrition. The article further highlights recent scientific advancements, including the potential of microbiota-based interventions such as probiotics, prebiotics, dietary modulation, and fecal microbiota transplantation. By analyzing emerging research, we provide insights into how targeting the gut microbiota could offer novel, personalized, and sustainable solutions to two of the most persistent nutritional disorders of the 21st century.

2. Understanding Gut Microbiota

Gut microbiota are the resident microorganisms present in our gastrointestinal tract that form a distinct ecosystem and co-exist in a symbiotic relation with us [1]. Their primary role is to gain nutrients and take essential foods from the food we intake. Thought to have been a lucky evolution, these bacteria assist us in breaking down specific proteins and compounds to digestive forms that the intestine can then reabsorb. These organisms also assist in the immune response and train the system to attack a bigger threat [2]. However, the composition of these bacteria is unique, as not only do symbiotic bacteria reside here, but parasitic bacteria also make their home here. These bacteria fight for their niche with positive bacteria, and hence, a never-ending war ensues, with the two sides fighting. If the negative side wins, we get various illnesses like Food Poisoning and Diarrhea. The gut bacteria are affected primarily by nutrition and diet, accumulation of specific bacteria due to local food intake, and, more importantly, whether the person was delivered through a C-section or a vaginal birth, and also, whether the person was breastfed or bottle-fed.

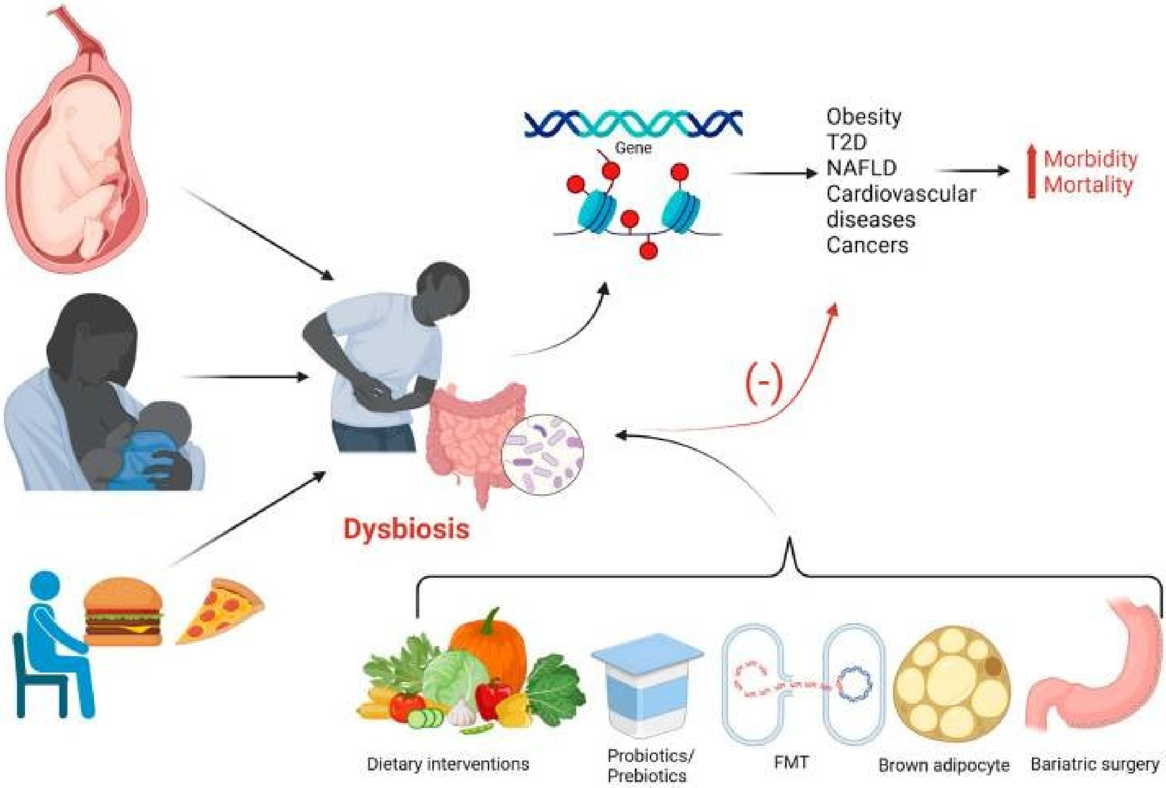

Figure 1. The human gut is shaped by the gut microbiota from a human's birth, gestation, and till full maturity. Various therapeutic interventions can help solve dysbiosis when the gut microbiome is not equilibrated. Reproduced with permission [39], Copyright 2024, MDPI.

All these factors help shape a unique microbiota spread in each individual, leading to distinct feeding habits and food intakes. Studies have even mentioned that gut bacteria affect our food preferences and lead to a desire for certain foods [3]. These scenarios all present this living ecosystem as a vital part of our body that shapes our health in an important way. Not maintaining and/or sustaining this ecosystem can lead to disarray of gut health and possible illness, ranging from Ulcers to colorectal cancer (CRC). The disruption of the state of homeostasis among members of the gut microbiota may cause imbalances among bacterial communities residing in the intestine, a situation that is referred to as Dysbiosis [4]. This condition leads to the buildup of imbalances in the intestinal tract. There are certain conditions in which gut bacteria are altered, like Alzheimer's, autoimmune, vascular diseases (like plaque buildup), etc., that lead to alteration of gut bacteria that can be either helpful or extremely troublesome [5].

3. From Deficiency to Excess: The Spectrum of Nutritional Disorders

According to WHO**,** Obesity is a chronic metabolic disorder that results from the excessive build- up of certain specific fats, leading to illness and increased mortality. Medically, it is an overweight individual as someone having a body mass index (BMI, i.e., the weight in kilograms divided by the height in meters squared) between 25.0 and 29.9 kg/m2, and an obese person as someone with a BMI greater than or equal to 30.0 kg/m2. It is a result of the absence of exercise, excessive stress, and an unbalanced diet, and as a side effect of certain medicines or diseases. To sum it up, it is caused by a bad lifestyle. To emphasize, according to the Centers for Disease Control and Prevention, the USA, it not only affects the economically rich but also the middle class and certain poverty classes as well. Neither does obesity result from having too much fat intake, but also results

from excessive consumption of other foodstuffs.
Obesity is a complex, chronic, and very present socio-health issue that has led to discrimination, negligence, and medical complications that make it one of the most feared diseases [6]. However, it seems this condition is also the most prominent in the world, specifically the Western world, where high sugar intake is common in most households. The worldwide prevalence of obesity has doubled during the last 30 years, and consequently, the WHO has declared obesity a global epidemic. This shows the negligence humans are giving to this condition as an annoyance, remedied by the gym and diet. However, it is extremely difficult for an obese person to overcome their condition solely through strenuous physical activities. Often, obese people diet and exercise like their non-obese-but-still-not-fit counterparts, leading to more chronic issues like arthritis, gastritis, as their bodies are not used to these sudden changes. Hence, these individuals have to look at their weakness from a medical perspective and seek health treatment, which they often neglect, worsening this vicious cycle. It is widely accepted that a high level of microbial complexity, i.e., a high number of different microbial species present in healthy adult subjects, plays an important role in maintaining immune homeostasis. This shows that the microbiota and obesity are interrelated situations and demand an interconnected treatment and approach toward solving these issues.
According to WHO**,** Malnutrition is defined as a deficiency, excess, or imbalance of a wide range of nutrients, resulting in a measurable adverse effect on body composition, function, and clinical outcome. Unlike its supposed counterpart, malnutrition does not have a certain look or a morphological identification that we can detect easily. Instead, the malnourished are categorized by their behavior and habits; they eat very little, very low diversity, or tend not to have access to proper food. When any of the essential carbs like monosaccharides, lipids, proteins, or fats are consumed too little or none at all, then the person gets malnourished. This means that Obesity and Vitamin toxicity are also a part of this condition, and so are (most) nutritional deficiencies like Beriberi, rickets, and Scurvy [7]. This extremely broad definition encompasses the profound impact of malnutrition. It does not only mean swollen abdomen and ribs but also emotional disturbances and breakdowns. Food for our body is an extremely vital component, so when we do not get enough of it, it results in such a condition. This condition affects mostly underprivileged communities. Recently, double Burden Malnutrition is commonly seen in various communities that experience both Malnutrition and overnutrition**.** This extreme difference in dietary standards of people from the same resource location and similar physical environments tells us that malnutrition is not limited to food and location availability, but also genetics and previous conditions. Genetics, in context, that leads to malnutrition when the body doesn't have the required microbial acids to break down certain nutrients properly, leading to deficiencies [8]. Malnutrition leads to various issues like increased morbidity and mortality, impaired growth and development, increased risk of chronic diseases, reduced productivity, and an economic burden to the family. It reduces cognitive functionality in young humans and leads to impairment [9]. To combat this illness, improvement of food security and national practices must be executed. Infections must be treated effectively, and supplementation must be given on time. Addressing the various socio- economic factors is essential to eliminate malnutrition in less developed areas.

4. Malnutrition Through a Microbial Lens

Gut biome is a symbiotic relationship between us humans with an intricate gut microbiota that has continued for a millennium and has evolved with us through time [10]. Malnutrition, on the other hand, is the deficiencies or excesses of nutrients that adversely affect the body's tissues and functions. It includes both undernutrition and overnutrition [11]. Both malnutrition and gut bacteria are glass-like conditions, extremely shatterable at the slightest pressure and delicate in nature. To understand this relationship, let us take the example of malnourished children. Children with severe acute malnutrition and modern acute malnutrition often have a "stunted" or "immature" less developed gut microbiome [12]. It is characterized by reduced diversity, altered functional capacity, and a persistence of "opportunistic bacteria. This immature gut microbiome leads to various problems that relate to malnutrition [13]. A dysbiotic gut microbiome may produce fewer beneficial short-chain fatty acids. These SCFAs play vital roles in the gut microbiome, ranging from energy production to lipid utilization and much more [14]. Digestion is also compromised, as the limited or absence of certain bacteria leads to improper digestion of certain species.

The most important aspect of gut microbiota is the ability of certain gut microbiota to digest certain compounds that produce vitamins. B Vitamins and K vitamins are obtained this way, and dysbiosis leads to impairment of the bioavailability of these crucial micronutrients [14]. The immune system is also negatively affected by dysbiosis. A healthy gut trains the immune system against future attacks as well as defends its niche away from opportunistic invading species. Hence, gut microbiota plays an essential role in fighting against malnutrition and protecting against obesity and other metabolic disorders [15].

5. Microbial Signatures of Obesity

Gut microbiota and Obesity are the areas of intense medical interest in the present health community. While one is an enigmatic and unique evolution, the other is a result of modernization and urbanization. Gut microbiota is one of the most intriguing parts of our body [16]. An individual ecosystem evolved from millennia inside the acidic and frankly, uninhabitable gastrointestinal system; these communities of diverse bacteria influence a lot of us, our Metabolism, Energy Balance, and, ultimately, Body Weight. Obesity, on the other hand, is, according to WHO, "abnormal or excessive fat accumulation that presents a risk to health". Obese individuals often exhibit a different gut microbial composition, commonly referred to as "dysbiosis". They tend to have decreased microbial diversity due to bad diet decisions, genetics, lifestyle, medications, and even early life development [17].

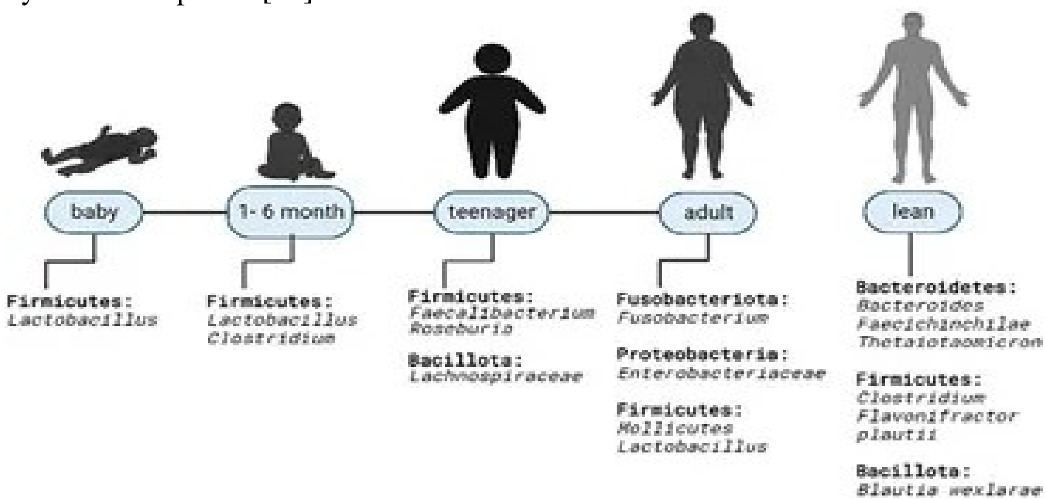

Figure 2. Microbiota modifications in different obese and lean individuals. Reproduced with permission [37] Copyright 2022, Frontiers

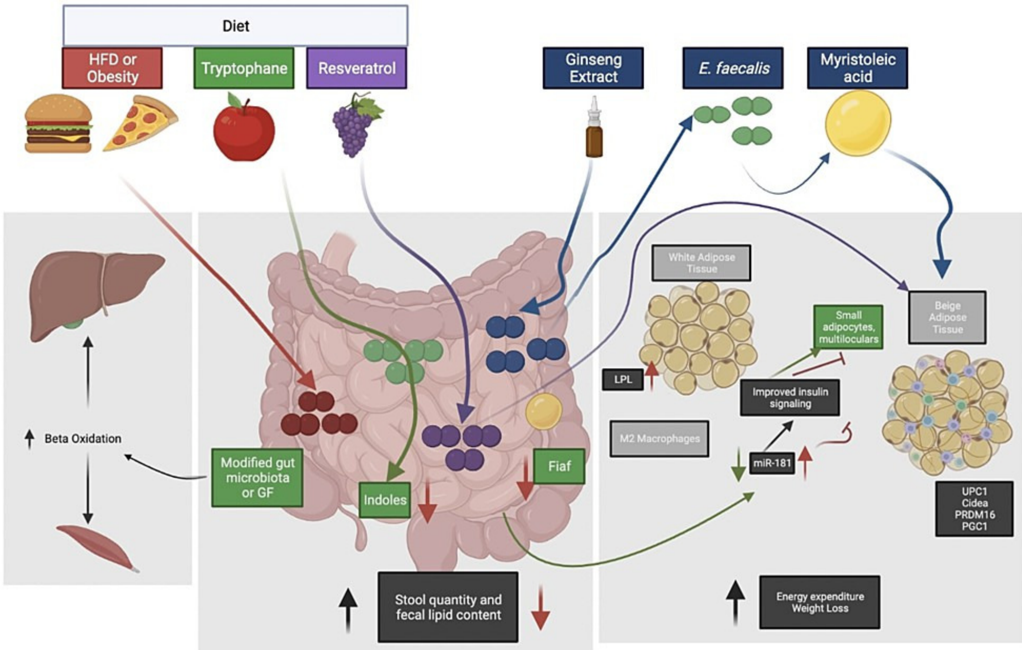

Figure 3. Changes in intestinal microbiota due to different triggers ultimately affecting weight storage and metabolic health in mice, Reproduced with permission [38], Copyright 2022, Springr

Gut bacteria also ferment indigestible carbohydrates (fiber) to produce SCFAs. While SCFAs can be beneficial, it is the excess of them that causes trouble in individuals (**Table 1**). Certain bacteria also result in low-grade chronic systemic inflammation of the gut lining, resulting in metabolic disorders [18]. Gut bacteria also influence the production of hormones that regulate fullness and hunger; ghrelin and leptin, respectively. Fluctuations in these hormones are what lead to food disorders, including obesity [19]. The gut-brain axis is also an integral part of this system, albeit a bit more complex. The Gut Microbiota influences food preferences, cravings, and reward pathways through releasing various chemicals that trigger various parts of the brain [20]. Various factors influence gut microbiota in relation to obesity. Intake of low-fiber foods naturally results in less diverse bacterial diversity, while fermented foods, leafy greens, and fruits tend to help increase the biodiversity inside the gut.[21]**.** This diversity allows for a more balanced ecosystem that helps avoid obesity as a whole [22]. Recent accumulating evidence indicates that the gut microbiome can affect the development and regulation of the hypothalamic-pituitary-adrenal axis and behaviour, with central integrative systems crucial in the prosperous physiological adaptation of the organism to external stressors.

Table 1. List of hormones involved with the gut microbiome

Hormone	Structure	Function	Reference
Estrogen (Estradiol, Estrone, Estriol)	Estrogen (Estradiol, Estrone, Estriol)	The "estrobolome" (enteric bacteria with the ability to metabolize estrogens) deconjugates estrogens, which permits reabsorption. Estrogen imbalance can result from dysbiosis.	[23], [24]
Androgens (Testosterone, Dihydrotestosterone (DHT))	Androgens (Testosterone, Dihydrotestosterone (DHT))	Gut microbiota can metabolize and de- glucuronidate androgens, influencing their bioavailability. Sex hormones also affect gut microbiota composition.	[25], [26], [27]
Progesterone	Progesterone	Can affect the growth of gut bacteria and their levels can be affected by the gut microbiome.	
Glucagon-like Peptide 1 (GLP-1)	Glucagon-like Peptide 1 (GLP-1)	Controls satiety and glucose metabolism. Gut microbiota (more specifically via SCFAs) can stimulate GLP-1 release from enter endocrine cells.	[28], [29]
Peptide YY (PYY)	Peptide YY (PYY)	Involved in satiety and intestinal motility. Microbiota-derived metabolites (SCFAs) are able to stimulate PYY secretion.	[30], [31]
Ghrelin	Ghrelin	"Hunger hormone." The influence of the gut microbiome on ghrelin is complex and perhaps composition-dependent.	[31]
Cholecystokinin (CCK)	Cholecystokinin (CCK)	Controls pancreatic enzyme secretion, gallbladder contraction, and satiety. Its release can be modified by microbiota.	[32]

6. Therapeutic Interventions Targeting Gut Microbiota

Present medical research has advanced quite early in the therapeutic Interventions Targeting Gut Microbiota and using it to combat disorders and illness with new angles and technology. Although it is difficult to cultivate anaerobic bacteria in the laboratory to have a firsthand analysis of their healing properties, fecal samples and intestinal samples have proved fruitful in filling the gaps and, as a result, have shown promise in therapies. As shown in **Table 2**, some preliminary research in certain cancers and general gastrointestinal infections has proved that the gastrointestinal biome is truly vast in this field. Gut microbiota is significant as the rise of microbiome-related infections increases, and many chronic illnesses like diabetes and colorectal cancer have been proven to be related to the gut microbiota. Using therapy to intervene and equilibrate this process is vital for the restoration of a damaged microbiome [33]. Probiotics come first to mind in this context. It has been documented through many clinical trials that probiotics could shape Antibiotic-Associated Diarrhea (AAD), Inflammatory Bowel Diseases, Crohn's Disease, and Colorectal cancer, all have concrete evidence that yes, human intestinal microbiota regulate the homeostasis present in the gut and maintain it. Prebiotics are the next step in understanding gut microbial health. Certain compounds exist: namely, carbohydrate prebiotics, which selectively encourage the growth of beneficial bacteria, their mechanisms of action, and benefits to human hosts. HMO, FOS (fructooligosaccharide), Inulin, GOS (galactooligosaccharides), MOS (Mannan-oligosaccharides), and XOS (Xylooligosaccharides)are a few prebiotic oligosaccharides that benefit the host by digesting certain components of complex sugars and fats [34]. Synbiotics thus work mutually in this context with synergy, helping the adjustment of strains both biotically and abiotically.

Table 2. Common diseases involving therapeutic interventions targeting gut microbiota

Disease	Peculiars	References
Clostridium difficile Infection (CDI)	*Clostridioides difficile* infection (CDI) is one of the most common healthcare-associated infections and aggressive action is required to combat this threat. Fecal microbiota transplantation (FMT) is the delivery of intestinal microbiota from a healthy donor to a recipient to mitigate disease by modifying the structure and/or function of the gut microbiota . FMT is currently recommended in the CDI treatment guidelines as an option at the second or subsequent recurrence . In addition to CDI treatment, including FMT, changes to underlying risk factors should be considered for their effect on the gut microbiota, such as discontinuing gastric acid suppressants or altering systemic antimicrobial therapy for a non-CDI infection.	[32]
Inflammatory Bowel Disease (IBD) - Croon's Disease and Ulcerative Colitis	Inflammatory bowel disease (IBD), comprising Crohn's disease (CD) and ulcerative colitis (UC), is characterized by chronic intestinal inflammation. The dysbiotic gut micro biome likely contributes to IBD pathogenesis. Microbiome-directed therapies such as fecal microbiota transplantation (FMT), probiotics, and synbiotics may help induce and maintain remission Manipulating the gut microbiota through microbiome interventions may modulate the enteric environment and immune responses in IBD,c casuing the patient relief and helping it to sustain more acute damage.	[33]
Irritable Bowel Syndrome (IBS)	Irritable Bowel Syndrome (IBS) is a functional gastrointestinal disorder characterized by chronic abdominal pain, bloating, and altered bowel habits. Gut microbiota dysbiosis has been increasingly recognized as a central contributing factor. This has led to growing interest in microbiota-directed therapies, including probiotics, prebiotics, synbiotics, antibiotics, dietary modifications, and fecal microbiota transplantation (FMT).	[34]
Autism spectrum disorder (ASD)	Autism Spectrum Disorder is a developmental disorder that is characterized by deficits in social communication and restricted, repetitive, and stereotyped behaviors. In addition to neurobehavioral symptoms, children with ASD often have gastrointestinal symptoms (e.g. constipation, diarrhea, gas, abdominal pain, reflux). Micro biota Transfer Therapy (MTT) / Fecal Micro biota Transplant (FMT) is the strongest evidence for improving GI symptoms that have shown the most positive results, with researches concluding that ASD might be	[35]
Type 2 Diabetes Mellitus	Diabetes mellitus is a chronic disease that occurs when the pancreas does not produce enough insulin or when the body cannot effectively use the insulin it produces, leading to elevated blood glucose levels. Alterations in gut micro biota composition can substantially impact metabolic parameters and glycemic control in both type 1 and type 2. Interventions such as FMT and probiotic supplementation show promise in enhancing clinical outcomes, emphasizing the need for micro biome-targeted therapies in diabetes care. However, recent studies in this filed are knly tested in zoological lab tests within a controlled environement, so a conclusive treatment outside it remains inconclusive.	[36]

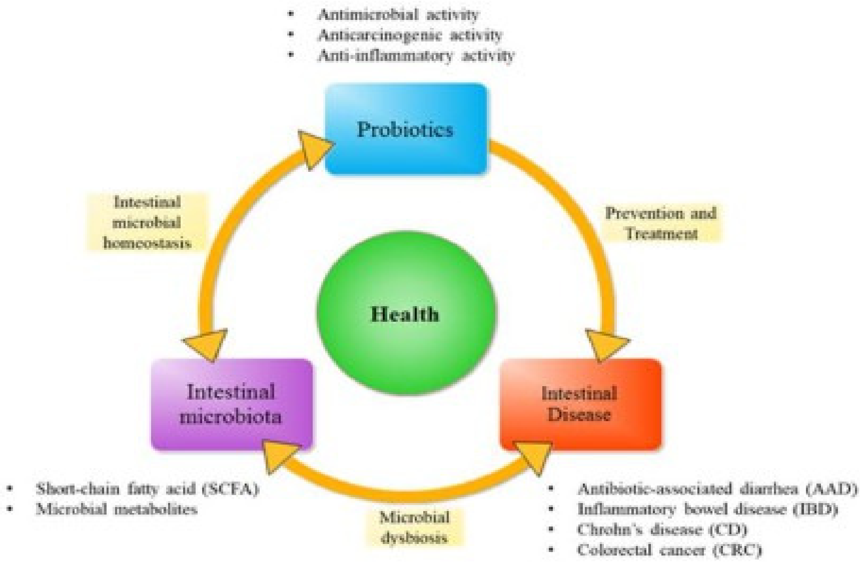

Figure 4. Interrelationship between probiotics, intestinal diseases, and microbiota., Reproduced with permission [41]**,** Copyright 2019, JMB

Fecal Microbiota Transplantation (FMT) is the most popular and famous therapeutic intervention involving the transplant of fecal matter from a healthy donor to a recipient. Various applications in the field of IBD, IBS, and metabolic syndrome are a common feature of this treatment. Phage therapy is the last of this therapy, which is clinically tested and has shown promising results, where bacteriophages are used to kill pathogenic bacteria. This is a highly specialized way of killing bacteria involving certain interventions, and as antibiotics start becoming ineffective, bacteriophages, as bacteria's natural predators, offer a powerful advantage over antibiotics, namely that they can be highly specific, targeting only their host bacteria, suggesting a milder therapy towards niche microbiota. The possibilities of therapeutic intervention in microbiome are broad and since the early 1900 century, a vital tool for combating illness. Hence, by developing better tools in combating non-communicable diseases, we can rely on these technologies for the foreseeable future.

7. Conclusions

The complex interplay between gut microbiota, obesity, and malnutrition underscores the need for a holistic approach to addressing these health challenges. Factors such as diet, genetics, lifestyle, and even birth delivery methods shape the gut microbiome, influencing an individual's susceptibility to these conditions. Gut dysbiosis is a key factor in both conditions, affecting metabolism, immunity, and overall health. Therapeutic interventions aimed at restoring a healthy gut microbiome offer promising avenues for treatment, but a comprehensive approach that considers individual factors is essential for successful outcomes. Effective interventions must consider this multifaceted nature, integrating microbiome-targeted strategies with conventional approaches to achieve lasting results.

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