

## The path to gut homeostasis: diet, microbiota, and human wellness



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### Abstract

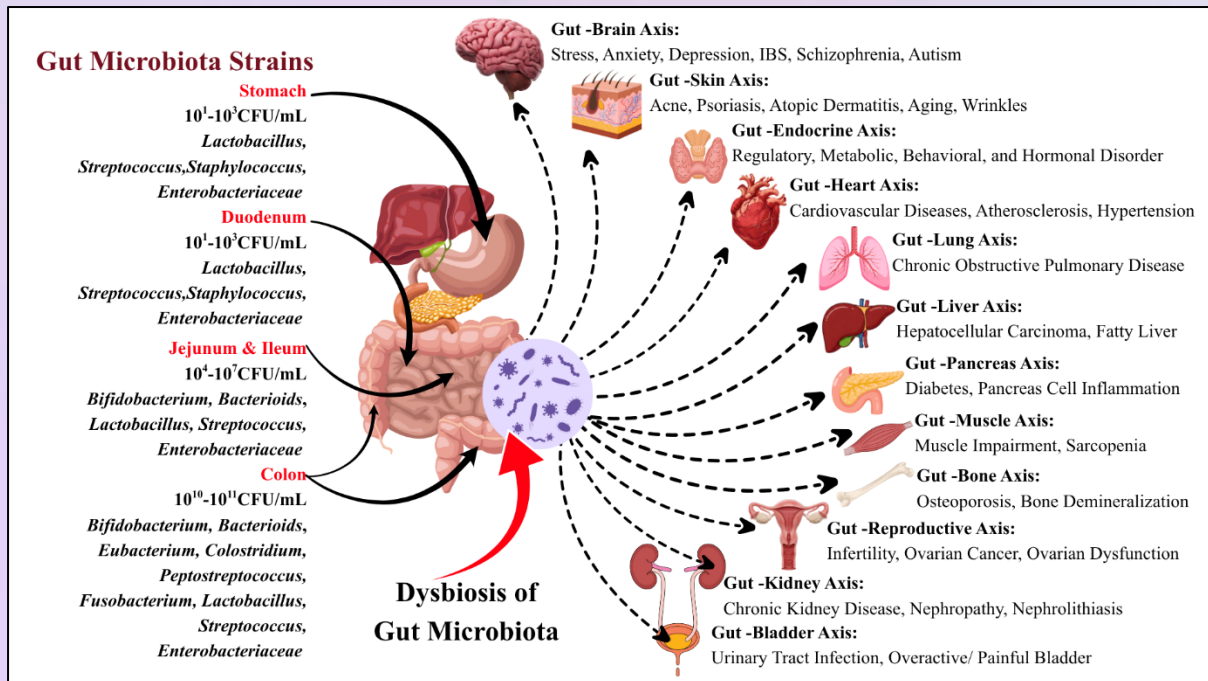
Gut homeostasis, a state of dynamic equilibrium between the host and its intestinal microbiota, is fundamental to metabolic, immunological, and neurological health. This review outlines the association between diet, lifestyle, and the impact it has on the digestive system and the cells that line the walls of the gut. Consuming a diet rich in whole plant foods, fermented products, and prebiotics can stimulate beneficial microbes in the gut and keep the body's internal defense system, or immune system, in balance. In the Western part of the world, dysbiosis, barrier compromise, and inflammation are caused by the usual Western diet. Emerging technologies enable evidence-based, Individualized Treatments That Prevent Disease by optimizing an Individual's Microbiome. Modifying nutrition and daily habits to restore the balance of gut bacteria may be key to treating specific diseases caused by an imbalanced gut microbiome.

**Keywords:** Gut Microbiota, Homeostasis, Dietary fibres, Dysbiosis

### 1. Introduction

The gut microbiota refers to the organisms living in a human gut that contribute to the host's physiology, which includes digestion, energy homeostasis, immunity, and neuro-cognition (1). Mutual signalling between the microbes and intestinal epithelium brings about gut homeostasis, which is an important dynamic balance to prevent diseases and maintain well-being. The disturbance of this balance is referred to as dysbiosis, which is associated with the development of a wide range of diseases. Understanding how microbes and our bodies

communicate and how that becomes disturbed is key to creating successful new treatments that target our microbiome or microbiota.



**Figure 1.** Dysbiosis of Gut Microbiota

## 2. Overview of the Gut Microbiota and Homeostasis

The human digestive system has more than 100 trillion organisms, such as bacteria and viruses (2). Maintaining gut homeostasis allows our gut to efficiently absorb nutrients as well as synthesise colonic metabolites like vitamins and short-chain fatty acids. Furthermore, gut homeostasis helps to maintain mucosal barrier integrity, limiting overgrowth of pathogens (3,4).

The ongoing two-way dialogue between commensal microorganisms and the intestinal epithelium, as well as resident immune cells, maintains this balance, which regulates host metabolism, enhances defence against enteric infection (2).

## 3. Mechanisms Sustaining Gut Homeostasis

The variety of relationships between the host and the microbiota helps us maintain gut homeostasis through mutualism. The selective epithelial barrier, composed of a mucin-rich mucus layer and tight-junction proteins, spatially confines microbes while allowing some nutrient and signalling molecules across (2). Secretory IgA serves an important purpose in the immune system by coating commensals to prevent unnecessary inflammation while maintaining the innate and adaptive immune response to pathogens (3). Microbial metabolites, especially the short-chain fatty acids and tryptophan catabolites, increase epithelial barrier integrity and control the inflammatory pathways and immune cell differentiation (5). The body of organisms should be in sync with the environment. Overall, feeding–fasting cycles help in entraining the microbes. With nutrients, they should be in a cyclic manner like the body (6,7).

**Table 1.** Multifaceted Actions of Gut Microbiota in Homeostasis

Function	Key Microbial Contribution	Host Impact
Nutrient Metabolism	Breaks down fibres to SCFA, synthesizes vitamins	Energy, colon health, and immunity
Barrier Integrity	Produces butyrate; interacts with mucins	Prevents pathogen invasion
Immune Modulation	Stimulates IgA, educates Tregs	Promotes tolerance/surveillance
Pathogen Exclusion	Competitive colonization, bacteriocins	Reduces infection risk
Drug/Xenobiotic Metabolism	Biotransforms compounds	Detoxification, efficacy

#### 4. Role of Diet in Shaping the Gut Microbiota

Diet is the most important and modifiable environmental factor that has an impact on the gut microbiome (6,8). The types, amounts, and availability of carbohydrates, fibres, proteins, fats, polyphenols, micronutrients, and the presence of fermented foods all sculpt microbial diversity and function (9).

##### 4.1. Dietary Patterns and Microbial Diversity

###### 4.1.1. Mediterranean Diet (MD)

- Rich in dietary fibre, polyphenols, and omega-3, and poor in processed products
- Enriches the genera *Bifidobacterium* and *Faecalibacterium*, thus increasing SCFA production and anti-inflammatory effects (6).

###### 4.1.2. Western Diet (WD)

- High in saturated fats, sugar, red meat, and processed foods
- Associated with a decrease in microbiota diversity, an increase of pro-inflammatory taxa (e.g., *Proteobacteria*), and decreased SCFAs leading to the development of metabolic inflammation (3,6).

###### 4.1.3. Plant-Based Diets (Vegetarian, Vegan)

Greater concentrations of fiber-fermenting (*Prevotella*, *Lachnospira*) and SCFA-producing bacteria; lower in pathobionts (10).

**Table 2.** Dietary Influence on Major Gut Microbial Taxa

Diet Type	Key Microbiota Shift	Noted Health Impact
Mediterranean	↑ <i>Bifidobacterium</i> , <i>Lachnospira</i>	SCFAs ↑, inflammation ↓
Plant-based	↑ <i>Prevotella</i> , <i>Roseburia</i>	Diversity ↑, insulin sensitivity

Western	↑ <i>Proteobacteria</i> , ↓ <i>Bacteroidetes</i>	SCFA ↓, inflammation ↑, obesity
Fermented-rich	↑ <i>Lactobacillus</i> , <i>Bifidobacterium</i>	Barrier, immune ↑, inflammation ↓
High-protein	Modulates <i>Akkermansia</i> , butyrate ↑	Metabolic effect, gut barrier+

## 4.2. Dietary Components and Their Microbial Effects

### 4.2.1. Fibers and Prebiotics

Dietary fibers (especially resistant starch, inulin, and fructooligosaccharides) that escape small intestinal digestion are fermented by the gut microbiota, predominantly resulting in the production of SCFAs (7). Prebiotics promote the selective growth of beneficial microbes (*Bifidobacterium* and *Faecalibacterium*), enhance barrier function and immune system modulation, and reduce systemic inflammation (6). Whole grain consumption (i.e., oats and barley) has also been observed to increase *Bifidobacterium* and *Lactobacillus* in a randomized controlled trial, while decreased microbiota diversity and lower SCFA production were associated with consumption of refined grains (6).

### 4.2.2. Polyphenols and Plant Bioactives

Polyphenols (flavonoids, anthocyanins, and carotenoids) from colorful vegetables, berries, and beverages alter gut microbe species composition such that SCFA-producers are increased while toxin formers are decreased (7, 9). There are two-fold health effects: polyphenols undergo microbial conversion into bioactive metabolites, but also promote the growth of anti-inflammatory commensals (6).

### 4.2.3. Fermented Foods and Probiotics

The direct supplementation of *Lactobacillus* and *Bifidobacterium* strains, as well as fermented milk and vegetable products (yogurt, kefir, kimchi, or sauerkraut), enriches the local SCFA pool and strengthens immune functions (11).

### 4.2.4. Protein and Amino Acid Modulators

The gut microbiome structure and gut immune function are influenced by the type and quality of protein, including the supply of specific amino acids (tryptophan, glutamine) consumed. Metabolites from tryptophan degradation contribute to immune signaling, enhance mucosal fortification, and modulate the microbiome toward eubiotics (11).

### 4.2.5. Fats and Emulsifiers

High amount of saturated fat exposure raises the *pathobiont Bilophila wadsworthia*, a microbe linked to colitis, whereas omega-3s, incorporating polyunsaturated fats, support anti-inflammatory bacteria (6).

## 5. Microbial Metabolites: Key Mediators of Health

Intestinal microbes produce metabolites that are important for host physiology, and the most significant of these include short-chain fatty acids (butyrate, acetate, propionate), tryptophan catabolites 143, bile acids 144, and specific vitamins (B group, K) (7).

- Butyrate is beneficial for colonocyte health, barrier function, and has wide-ranging anti-inflammatory actions.

- Acetate and Propionate control hepatic metabolism, gluconeogenesis/lipid synthesis, as well as appetite and glucose homeostasis (5).
- Other Metabolites: Secondary bile acids regulate cholesterol, and indole metabolites of tryptophan mediate mucosal immunity (11).

**Table 3.** Microbial Metabolites and Functional Outcomes

Metabolite	Microbial Origin	Host Benefits
Butyrate	<i>Faecalibacterium prausnitzii</i> , <i>Roseburia</i>	Barrier, anti-inflammatory, fuel
Propionate	<i>Bacteroides spp.</i> , <i>Akkermansia</i>	Glucose regulation, satiety
Acetate	Multiple commensals	Lipid metabolism, immune modulation
B-vitamins	<i>Bifidobacterium</i> , <i>Lactobacillus</i>	Energy metabolism, CNS development
Indole/tryptophan	<i>Clostridium</i> , <i>Bacteroides</i>	Mucosal immunity, signaling

## 6. Dysbiosis and Disease: The Flip Side of Imbalance

While eubiosis is associated with health, dysbiosis (reduced diversity, pathogenic overgrowth) is related to several diseases:

- **Metabolic Syndrome/Obesity:** WD-mediated dysbiosis results increased calorie extraction, endotoxemia (contributing to insulin resistance), and pro-inflammatory SCFA patterns<sup>43 53</sup> Leptin Resistance/Metabolism (hormone secretion); Chronic alcohol consumption is associated with significantly lower levels of serum leptin<sup>44</sup> and villus Leptin receptor<sup>45</sup>), which can probably be over-ruled by the effect of reducing exposure to irrelevant danger signals (5,12).
- **IBD (Crohn’s Disease, Ulcerative Colitis):** Loss of butyrate-producers compromises barrier, activates mucosal inflammation, and maintains relapsing cycles (6).
- **Neurological Disorders:** Links from gut-brain axis through microbiota-derived metabolites and vagal nerve signals to inflammation and cognitive function (1,4).
- **Autoimmunity and Allergies:** Broken immune-microbe tolerance promotes hypersensitivity observed in experimental and clinical work (2).

## 7. Dietary Strategies for Microbial Balance and Human Wellness

A wealth of evidence supports several strategies for promoting gut homeostasis and wellness:

- **Increase Plant-Based Diversity:** Every plant species provides a new taxon. >30 plant foods/week favors the richest microbiota (10).
- **Eat Whole Grains and Legumes:** These foods contain emerging beneficial bacteria and short-chain fatty acids that play an important role in metabolism and immune health (6).

- **Eat fermented, synbiotic Food:** Daily consumption strengthens the number of friendly microbe communities (11).
- **Choose Good Fats:** Omega-3 rich/n-6 balanced (anti-inflammatory fats) oils support positive eubiotic profiles, while reducing proinflammatory taxa (7).
- **Limit Excessed Processed Sugars, Emulsifiers, and Additives:** These drive dysbiosis and are linked to barrier dysfunction (9).
- **Personalize/Individualize Regimens:** Periodic monitoring and addressing individual microbial signatures with the help of sequencing and biomarker feedback (6).

**Table 4.** Practical Dietary Approaches for Gut Well-being

Actionable Strategy	Microbial Outcome	Health Benefit
30+ plants/week	↑ Diversity (fiber fermenters)	Resilience, lower risk
Whole grains daily	↑ <i>Bifido</i> , SCFA	Glucose, weight control
Daily fermented food	↑ <i>Lactobacilli</i> , <i>Bifido</i>	Barrier, anti-inflammation
Limit processed foods	Dysbiosis risk ↓	Lower metabolic syndrome
Mediterranean/plant-rich diet	↑ SCFA, anti-inflammatories	Metabolic/cardiac benefit

## 8. Future Directions: Personalized Nutrition & Microbiome Medicine

Advances in precision nutrition and digital health now allow the continuous monitoring of diet, metagenomic profiling of the gut microbiome, and personalisation of dietary recommendations. The enhanced interventions, such as second-generation probiotics or synthetic *Christensenella* spp, postbiotic compounds, and personalized synbiotic formulations, are going beyond laboratory research for clinical trials (6).

Simultaneously, machine learning algorithms would be able to use individual microbiome signatures to predict personalized glycemic responses, inflammatory biomarkers, and SCFA production profiles (7).

## 9. Conclusion

The balanced coexistence of gut microbes relies on different types of fibre as well as food products with plant nutrients. Prebiotic, probiotic, or synbiotic food products and low consumption of ultra-processed products also support gut homeostasis. Utilizing microorganisms' modulation through focused nutrition and advanced technologies may help in

preventing dysbiosis-related diseases. Future clinical practice, public health policy, and lifestyle guidelines must preserve and enhance this balance for healthy generations.

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