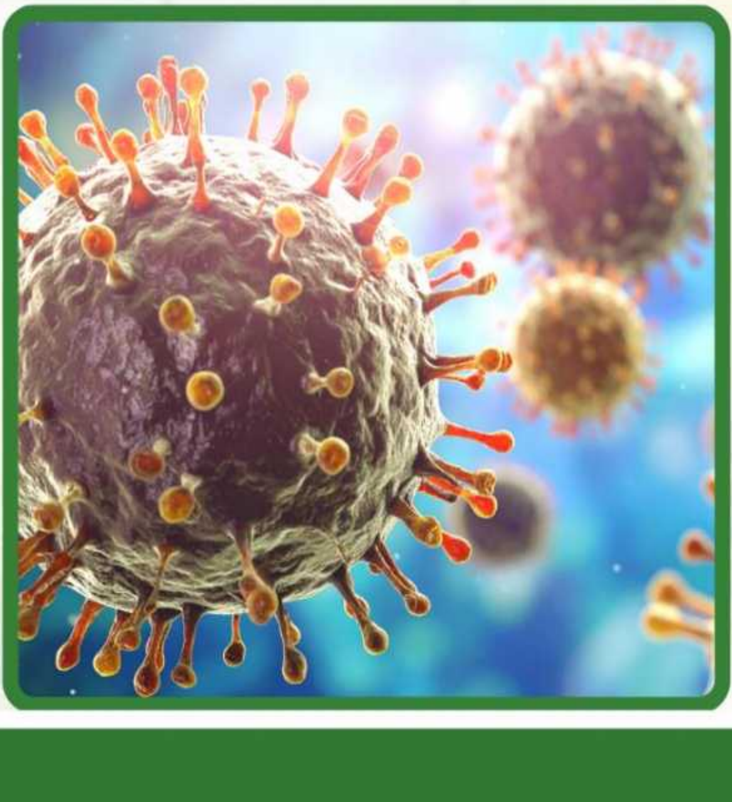
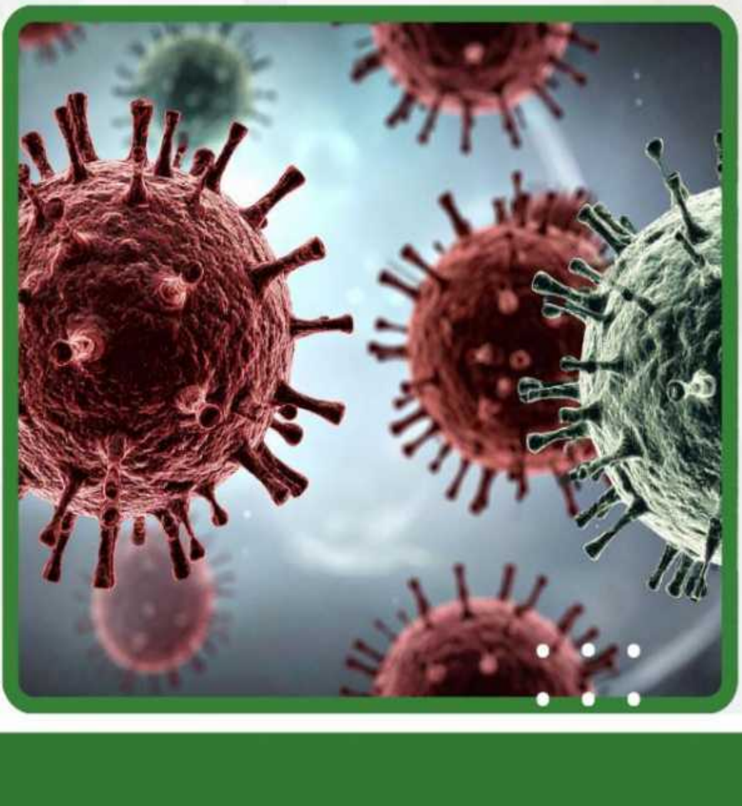
rebioin journal
OF BIOSCIENCES

MICROBES AFFECTING MENTAL HEALTH





admin@reboin.com
www.rebioin.com

MICROBES AFFECTING MENTAL HEALTH

Saloni Sharma
M.Sc. Microbiology, JECRC University, Jaipur, Rajasthan

Abstract

Intricate relationships between the human microbiome and mental health have garnered considerable attention lately in various scientific circles rather quietly. Trillions of microorganisms inhabit our bodies and play a crucial role modulating brain function, rather deeply influencing mood, cognition, and behaviour somehow. The project elucidates the complex interplay between the microbiome and mental health, focusing on bidirectional communication pathways via the gut-brain axis extensively nowadays. Microbial dysbiosis impacts mental health outcomes severely, and this will be investigated deeply using cutting-edge microbiology techniques alongside neuroscience and psychology frameworks. We will examine the impact of altered gut microbiota on the production of neuroactive compounds like neurotransmitters and hormones and their influence on brain function somewhat aberrantly. Our study will explore the role of microbe-derived metabolites in heavily modulating the immune system, with a focus on crosstalk between the gut microbiome and the hypothalamic-pituitary-adrenal axis, pretty thoroughly. We will delve into potential therapeutic uses of microbiome-targeted interventions, including probiotics and prebiotics, for prevention and treatment of various mental health issues vigorously nowadays. Ultimately, this project seeks to advance understanding of the microbial-mental health axis, providing critical insights into the development of novel microbiome-based therapies for the management of various mental health conditions ordinarily. Unravelling complex microbial brain function dynamics unlocks novel mental health disorder prevention strategies, improving lives worldwide for millions of people greatly.

***Keywords*:** Gut-brain axis, Mental health, Gamma-aminobutyric acid (GABA), Probiotics

1. Introduction

The human gut is home to an astonishing 100 trillion microbes, outnumbering our own cells by a factor of 10. Collectively, these microbes possess a genetic store that is 150 times larger than that of their human host. Their gene products play a key role in metabolism and overall health, forming a lifelong, mutually beneficial relationship with us.

Unicellular life has been present throughout the evolutionary history of multicellular organisms. Humans and other hominids have coevolved with their gut bacteria for at least 15 million years. This close bacteria-host interaction suggests that many biological and psychological characteristics of the host may be influenced by the symbiotic relationship with the commensal bacteria. [1]

Recently, microbiome research, particularly gut microbiota and their interactions with human mental health, has drawn remarkable attention; however, few Asian studies have addressed it. This new field of research known as the microbiota-gut-brain axis explores how these interactions between microbes found in the gut and the central nervous system (CNS) could potentially play a significant role in a number of neuropsychiatric disorders. This literature analytical response showcases a complex interrelationship between neurochemical production, immune modulation, and ultimately behavioural consequence; thus, it is pertinent to explore the current findings and define knowledge for future research. [3]

The composition of gut microbiota varies throughout the digestive system. The stomach and small intestine harbour relatively few bacterial species (Guarner & Malagelada, 2003), whereas the colon supports a highly dense microbial ecosystem, containing up to 10^{12} cells per gram of intestinal content. The microbial diversity in the gut includes approximately 300 to 1000 species, though the majority—around 99%—come from just 30 to 40 species (Michael, 2016). Due to their high presence in the digestive tract, bacteria contribute to nearly 60% of the dry mass of feces[4]. In addition to bacteria, the gut microbiota includes fungi, protists, archaea, and viruses, though their roles are less well understood. While the majority (99%) of gut bacteria are anaerobic, the cecum harbours a significant population of aerobic microbes[2]. The most common bacterial phyla in the gut are *Firmicutes, Bacteroidetes, Actinobacteria,* and *Proteobacteria*. Within these groups, dominant genera include *Bacteroides, Clostridium, Peptococcus, Bifidobacterium, Eubacterium, Ruminococcus, Faecalibacterium,* and *Peptostreptococcus* (Michael, 2016). Among them, Bacteroides is the most abundant, making up around 30% of the gut microbiota, highlighting its critical role in human health (Ann & Fergus, 2006). **[5]**

The relationship between SARS-CoV-2 infection and mental disorders was investigated in a prior systematic review and meta-analysis, while mental health disorders linked to Lyme borreliosis have been examined in a PRISMA study. A search was conducted in this study to find distinct microorganisms associated with two behaviours of particular concern in psychiatric patients as well as five mental diseases with the highest psychiatric disability[6]. The microbes associated with these conditions included *Aspergillus, Babesia, Bartonella, Borrelia* species (including the relapsing fever group and *Borrelia burgdorferi*), *Borna* disease virus, *Candida*, *Chlamydia*, SARS-CoV-2 (COVID-19) and other coronaviruses, *cytomegalovirus, enterovirus, Epstein–Barr virus, hepatitis C virus, herpes simplex virus, human endogenous retroviruses, human herpesvirus-6, human immunodeficiency* virus (HIV), human T-cell lymphotropic virus type 1 (HTLV-1), *Plasmodium*, *Influenza viruses*, measles virus, *Mycoplasma*, congenital rubella virus, *Shigella*, group A *Streptococcus*, *Toxoplasma gondii*, *Taenia solium*, *Treponema pallidum* (syphilis), *varicella-zoster* virus, and alterations in gut microbiota composition. [7]

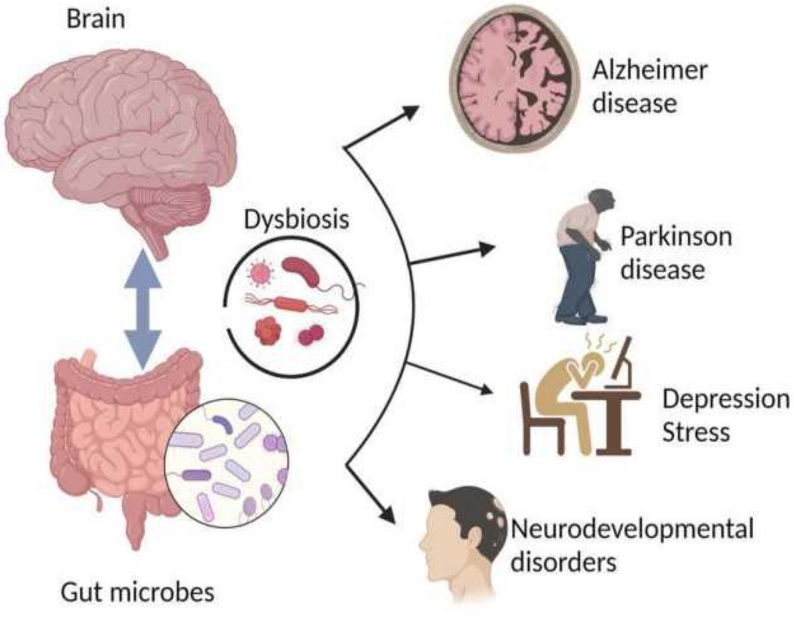


Figure 1: Diseases associated with gut health. *Ullah, H.,*

Arbab, S., Tian, Y., Liu, C., Chen, Y., Qijie, L., Khan, M. I., Hassan, I. U., & Li, K. (2023). The gut microbiota–brain axis in neurological disorders. Frontiers in Neuroscience, 17, 1225875. https://doi.org/10.3389/fnins.2023.1225875

Figure 1 Illustrates how the gut-brain axis links gut microorganisms to brain health. It demonstrates how brain function can be adversely affected by dysbiosis, an imbalance in the composition of gut microbes. Numerous neurological and psychological illnesses, such as Parkinson's disease, Alzheimer's disease, depression, stress, and neurodevelopmental problems, are associated with disturbed gut flora. Changes in gut health can have an impact on mental and neurological health, and vice versa, because the gut and brain communicate in both directions. The significance of gut health in brain-related illnesses is highlighted by the possibility that maintaining a normal gut microbiome may promote cognitive and emotional well-being.

Table 1: Overview of selected potentially harmful and potentially beneficial bacteria present in our body[8].

BACTERIA (GENUS)	BASIC FEATURES	ASSOCIATED PHYSIOLOGIC CHANGES	ASSOCIATED DISEASES STATES
***Lactobacillus* spp.**	Gram-positive facultative anaerobe	SCFA production; anti-inflammatory activity	• Attenuate IBD • Increased in fish oil-fed mice • Increased oral concentration after high-carbohydrate diet • Decreased obesity (*Lactobacillus plantarum, Lactobacillus paracasei*) • Increased obesity (*Lactobacillus reuteri*) • *Lactobacillus casei* strengthen immune system • Used as probiotic: *L. reuteri* prevents tooth decay • *Lactobacillus farciminis* prevent gut leakiness • *Lactobacillus rhamnosus* decreases stress and depression

			• Increased in autism and RTT syndrome
***Bacteroides* spp.**	Gram-negative obligate anaerobe	Activate $CD4^+$ T cells	• Increased with animal-based diet • Increased in obesity • *Bacteroides vulgatus* positively correlates with IR
***Bifidobacterium* spp.**	Gram-positive obligate anaerobe	SCFA production; improve gut mucosal barrier; lower intestinal LPS levels	• Decreased abundance in obesity • Decreased in smokers • Increased in RTT syndrome • Used as probiotic
***Christensenella* spp.**	Gram-negative anaerobe		• Negative correlate with BMI • *Christensenella minuta* decreased weight gain after transplant
***Roseburia* spp.**	Gram-variable obligate anaerobe	SCFA production	• Decreased in IBD • *Roseburia intestinalis* decreased in obesity • *R. intestinalis* decreased in T2D • Decreased in atherosclerosis
***Enterobacter* spp.**	Gram-negative facultative anaerobe		• Several spp. are pathogenic • Decreased after side-stream smoke exposure • *Enterobacter cloacae* induces obesity in germ -free mice
Escherichia coli	Gram-negative facultative anaerobe	TLR activation	• Increased in IBD • Increased in T2D
***Eubacterium* spp.**	Gram-positive obligate anaerobe	SCFA and phenolic acids production	• Decreased in IBD • Decreased in atherosclerosis • Decreased in T2D • Decreased in IBD • *Eubacterium saphenum* increased in periodontitis

Faecalibacterium prausnitzii	Gram-positive obligate anaerobe	SCFA production and anti-inflammatory effects	• Decreased abundance in IBD • Decreased in obesity • Decreased in T2D • Decreased with overweight
Gemella **spp.**	Gram-positive facultative anaerobe	Sugar fermentation	• Decreased oral concentration after smoke and tobacco use • Decreased in oral cavity of smokers
Streptococcus **spp.**	Gram-positive facultative anaerobe		• Some spp. are pathogenic • *Streptococcus agalactiae* and *Streptococcus pyogenes* increased in COPD • *Streptococcus mutans* increased in oral cavity after high-carbohydrate diet and correlated with caries • *Streptococcus salivarius* used a probiotic for periodontitis
Lachnospiraceae **spp.**	Gram-positive obligate anaerobe	Butyric acid production	• Increased after 24-week CS exposure in mice • Increased oral concentration after vitamin C administration
Bilophila **spp.**	Gram-negative obligate anaerobe	Promote pro-inflammatory immunity	• Increased in colitis • Increased in lard-fed mice • Decrease in autism
Neisseria **spp.**	Gram-negative obligate aerobe	Sugar fermentation	• Only two species are pathogenic: *Neisseria meningitidis* and *Neisseria gonorrhoeae* • Decreased in oral cavity of smokers • Decreased after smoke and tobacco use
Porphyromonas **spp.**	Gram-negative obligate anaerobe		• Several spp. are pathogenic • Decreased in oral cavity of smokers • Increased in obesity • *Porphyromonas gingivalis* and *Porphyromonas*

			endodontalis increased in periodontitis
***Dialister* spp.**	Gram-positive obligate anaerobe		• Several spp. are pathogenic • Increased in obesity • Increased in periodontitis • Decrease in autism
***Prevotella* spp.**	Gram-negative obligate anaerobe		• Several spp. are pathogenic, causing infections of the oral and respiratory tract • Increased with high-fiber diet • Increased in smokers with CD • *Prevotella copri* increased BCAA and insulin resistance • *Prevotella denticola* increased with periodontitis • Decrease in autism • Decreased in PD • Increased in UC
Akkermansia muciniphila	Gram-negative obligate anaerobe	Anti-inflammatory effects	• Decreased in IBD • Decreased in obesity • Decreased in T2D (but increased after metformin treatment) • Increased in fish-oil-fed mice • Decreased after cold exposure
***Staphylococcus* spp.**	Gram-positive facultative anaerobe		• Pathogenic • Increased in obesity • *Staphylococcus aureus* increased in COPD and atopic dermatitis
***Clostridium* spp.**	Gram-positive obligate anaerobe	Promote generation T_H17 cells	• Several spp. are pathogenic, causing botulism, tetanus, and so on. • Increased after sidestream smoke exposure • Decreased in IBD • Increased in autism and RTT syndrome • Positive correlation with plasma insulin and weight gain

			• Increased in T2D • *Clostridium perfringens* increased in old age.
***Veillonella* spp.**	Gram-negative obligate anaerobe	Fermentation of lactate to propionate and acetate	• Increased in oral cavity after smoking • Decrease in autism

1.2 The Microbiota-Gut-Brain Axis

A key factor in controlling the two-way communication between the gut and the brain is the gut microbiota. According to Cryan and Dinan (2012), gut microbiota has a major influence on behaviour and brain function through a number of communication routes, such as the vagus nerve and the immune system. Knowing how microbial metabolites can affect mental health, especially in relation to psychiatric conditions like schizophrenia, anxiety, and autism, requires a comprehension of these pathways. The potential of focusing therapeutic interventions on the microbiome is highlighted by the complex link between gut health and mental health. [1].

The vagus nerve serves as a crucial pathway for transmitting information about the gastrointestinal (GI) tract and other organs to the central nervous system (CNS), with approximately 20% of its fibers dedicated to GI–CNS communication (Forsythe, Bienenstock, & Kunze, 2014; Stakenborg et al., 2013). Notably, certain gut bacteria may only be able to influence neurological and psychological functions if the vagus nerve remains intact. This suggests that the vagus nerve acts as a direct communication channel between the gut microbiota and the brain[17].

Research supports this connection, as multiple studies have demonstrated that severing the vagus nerve disrupts both the beneficial psychological effects of commensal bacteria and the harmful effects of pathogenic bacteria. For instance, in mice, vagotomy eliminated the anti-anxiety effects of *Lactobacillus rhamnosus* (Bravo et al., 2011) and *Bifidobacterium longum* (Bercik, Park, et al., 2011), as well as the antidepressant properties of *L. rhamnosus* [22]. Similarly, when mice were exposed to pathogenic bacteria, those with an intact vagus nerve exhibited increased anxiety-like behaviours, whereas those that underwent vagotomy were protected from these maladaptive responses. [13]

Overall, these findings strongly suggest that the vagus nerve plays a key role in how gut bacteria influence psychological well-being. This emerging evidence opens up exciting possibilities for using the gut-brain connection to develop new mental health treatments. [9]

2. METHODS

2.1 Functional insights from simplified models of the human gut microbiome

The study of human gut microbiota is grounded in extensive research, with significant contributions to biology, particularly through investigations of *Escherichia coli*. Unlike many other gut bacteria, much of what is known about *E. coli* gene activity comes from direct biochemical, genetic, and genomic studies rather than homology-based annotation. However, despite its historical significance, *E. coli—along* with the broader phylum Proteobacteria—constitutes only a minor fraction of the human gut microbiota. Rather, gram-positive *Firmicutes* and gram-negative *Bacteroidetes* make up the majority of the dominating microbial populations.

E. coli Bacteroides *thetaiotaomicron* is another heavily investigated model gut commensal. Members of this species and related species are frequently found in the small intestine and colonic microbiota. HAP can regulate the importance of *B. thetaiotaomicron* for intestinal health, including the promotion of mucosal barrier maturation, the noncolonic fermentation of dietary plant polysaccharides after the weaning transition from breast milk to a solid diet, and resistance to enteric pathogens. Specifically, it excels at recognizing, uptake, and metabolism of complex polysaccharides derived from plants for which our body has limited capacity for full degradation. This has garnered a wide array of genetic and biochemical data to shed light on the metabolic enzymes and structural complexes associated with this function, including at the genetic level the genes associated with starch utilization.

2.2 Mechanisms of Influence

There are some mechanisms that have been found in studies demonstrating how our gut microbiota can affect our mental health. One of the most studied mechanisms is the production of neuroactive substances by gut bacteria. For example, Clapp et al. (2017) also showed that neurotransmitters are synthesized by gut microbiota, affecting brain function and behaviour, which is a biological link between gut health and psychiatric conditions. Also, circulating concentrations of kynurenines—the products of tryptophan metabolism—have been linked to exercise, inflammation, and mental health (Červenka et al., 2017). This suggests that gut microbiota not only plays a role in the synthesis of neurotransmitters but also interacts with environmental effects, which complicates the role of gut microbiota in mental health further. [2]

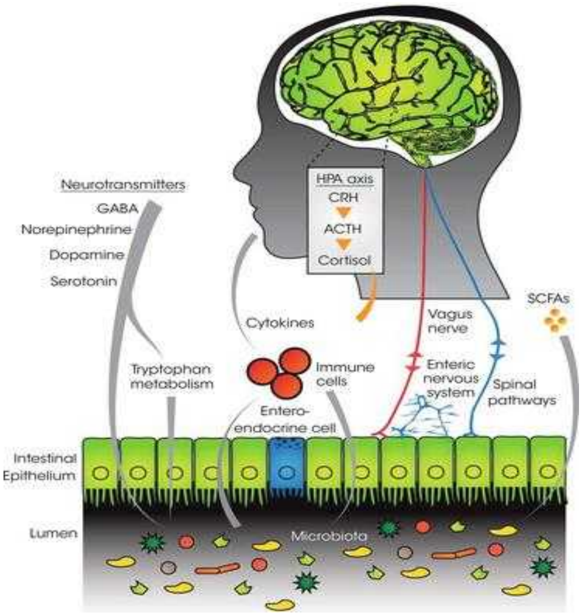


Figure 2: Gut-brain axis. *Dinan, T. G., Stilling, R. M., Stanton, C., & Cryan, J. F. (2015). Collective unconscious: How gut microbes shape human behaviour. Journal of Psychiatric Research, 63, 1-9. https://doi.org/10.1016/j.jpsychires.2015.02.021*

The above image illustrates the gut-brain axis; gut microbiota heavily influence brain function through neurotransmitters and immune signalling pretty much via vagus nerve signalling pathways somehow. The brain responds vigorously via the HPA axis, releasing a plethora of stress hormones rapidly. Bidirectional communication intricately regulates mood, stress, and gut health, highlighting the microbiome's profound role in multifaceted neurophysiological processes somehow.

According to one hypothesis, cytokines released in response to peripheral infection as well as components of bacterial cell walls activate particular classes of brain cells, especially microglia, which are the central nervous system's immune cells. This activation can release more cytokines and neurotoxic molecules such as the gas nitric oxide. Hence, disrupting neurotransmitter signalling can lead to mood and brain function disturbances.

Certain cytokines, including interleukin (IL)-1β, IL-6, and tumor necrosis factor-alpha (TNF-α), have the ability to cross the blood-brain barrier (BBB) and strongly stimulate the hypothalamic-pituitary-adrenal (HPA) axis. Additionally, bacterial components such as lipopolysaccharide (LPS) and peptidoglycan, which are key structural elements of bacterial cell walls, can also activate the HPA axis. Furthermore, *Escherichia coli* produces a ClpB protein that mimics α-melanotropin (α-MSH), a molecule that triggers the release of proopiomelanocortin, a precursor involved in the synthesis of adrenocorticotropic hormone (ACTH). [12]

As fundamental gut-healthy compounds, SCFAs (short-chain fatty acids) include acetic acid, butyric acid, and propionic acid. These compounds, generated from the fermentation of nondigestible carbohydrates by bacteria, have a variety of functions, including the maintenance of intestinal barrier integrity and suppression of immune-inflammatory responses [2]. Moreover, SCFAs are able to pass through the blood-brain barrier (BBB), where they play a role in the modulation of neuroinflammation by preventing the activation of local microglia and therefore decreasing localized inflammatory responses [16].

Disturbances in gut health, however, may result in difficulties. In diseases like "leaky gut," the intestinal lining's ability to function as a selective barrier that regulates the flow of nutrients and bacteria into the bloodstream may be weakened by long-term stress and other factors. When bacterial components or whole bacteria escape from the gut, they can trigger harmful inflammatory responses. Interestingly, certain probiotics have demonstrated the potential to mitigate these effects by restoring microbial balance and reinforcing gut barrier function.

“There really are a lot of mechanisms being uncovered right now,” notes Knight. Since different bacterial species influence distinct neural circuits and behaviours through varied pathways, translating these findings into clinical applications remains a complex challenge. “What matters is what’s relevant for what condition and for what species of bacteria,” he adds. “We’re getting into a situation where there are almost too many mechanisms where the gut can affect the brain.” [10]

Another key way the gut microbiota connects with the central nervous system (CNS) and the HPA axis is through direct communication between the enteric nervous system (ENS) and the vagus nerve. Some gut bacteria can even produce neurotransmitters, playing an active role in neural signalling. For instance, *Lactobacillus plantarum* produces acetylcholine, while dopamine is synthesized by *Bacillus, Proteus vulgaris,* and *Serratia marcescens*. Gamma-aminobutyric acid (GABA) is generated by *Lactobacillus* and *Bifidobacterium*, whereas *Citrobacter* and *Enterobacter* produce histamine. In fact, some bacteria, like *Bacillus, Escherichia coli,* and *Saccharomyces,* make norepinephrine. Serotonin is made by some different bacterial families, including *Candida, E. coli, Enterococcus,* and *Streptococcus*[21].

These microorganisms may also influence catecholamine transport and regulate tryptophan metabolism. The nucleus of the solitary tract, which receives input from the sub-diaphragmatic vagus nerve, plays a critical role in this process by activating the HPA axis through noradrenergic neurons. [11]

3. The Role of Probiotics

Probiotics have stealthily emerged as promising therapeutics in mental health, with growing evidence hinting at alleviating anxiety and depressive symptoms markedly. Research indicates probiotics can positively impact mood and mitigate anxiety by repopulating gut microbe balances and influencing nerves favourably (Clapp et al., 2017; Montiel-Castro et al., 2013). Gut bacteria play a crucial role in immune modulation, which has been heavily implicated in various pretty severe neuropsychiatric disorders recently. Further research into probiotics as potential mental health interventions is greatly underscored. [28].

Gut-derived peptides like leptin and ghrelin have been linked recently to various mental health disorders rather mysteriously and fairly extensively. Leptin plays a crucial role in energy homeostasis and is largely produced by adipose tissue and enterocytes residing in the small intestine. Ghrelin, often dubbed the hunger hormone, gets synthesized pretty quickly in the stomach lining and influences anxiety levels significantly somehow. Changes in gut microbiota can pretty severely disrupt the balance of various peptides, potentially affecting mental health badly over time. Prebiotics foster the growth of beneficial bacteria like Bifidobacteria and modulate levels of leptin and ghrelin, while certain antibiotics such as rifaximin impact these peptides too. No studies thus far have exhaustively scrutinized links between antibiotic usage, gut peptides, and risk of depression, anxiety, and other mental health disorders. A deeper mechanistic understanding of these interactions necessitates addressing this glaring research void pretty urgently nowadays. [15]

Gut dysbiosis has also been associated with reduced levels of serotonin and dopamine, two neurotransmitters essential for mood regulation (Wilson et al., 2023). Furthermore, disturbances in gut microbiota composition have been linked to increased stress-related inflammation, which may contribute to the pathophysiology of anxiety and depression. [16]

“Fermented foods are the original probiotics. They are full of different bacteria.”

Fermenting vegetables in brine ranks among ancient food preservation techniques used extensively centuries back. Fermentation thrives on lactic acid bacteria naturally present on raw veggies, and they proliferate remarkably during this biochemical process. Beneficial microbes enhance food's flavour remarkably and produce vitamins, minerals, and compounds with antimicrobial properties, supporting gut health very effectively. Fermented foods offer major benefits quite noticeably by introducing probiotics that help maintain a diverse gut microbiome and boost nutrient availability significantly. [18]

Chemoprevention strategies involving aspirin and cyclooxygenase-2 inhibitors have shown potential in reducing recurrence of adenomas in high-risk individuals quite effectively. Aspirin has been tenuously linked to lowered CRC (colorectal cancer) risk pretty frequently in fairly general populations. Both aspirin and nonsteroidal anti-inflammatory drugs harbour potentially deleterious side effects, necessitating meticulous risk-benefit assessments before being recommended for ubiquitous chemo-preventive usage. [14]

Retinoid-based therapy and tumor necrosis factor-related apoptosis-inducing ligand show promise in animal studies but need validation through human trials. Celecoxib usage has yielded somewhat lacklustre results in chemoprevention efforts targeting upper GI malignancies with dubious overall success. Endoscopic surveillance remains crucial pretty much for individuals at elevated risk of various GI cancers, quite evidently nowadays. [18]

4. Influence of Environmental Factors

Gut microbiota composition shifts rapidly under the influence of various lifestyle factors and environmental stressors quite frequently over time. Studies conducted rather recently by Gacesa and others shed new light on previously obscure aspects of certain biological phenomena. (2022) underscores the role of environmental influences in shaping the gut microbiome, which, in turn, affects mental health outcomes. Environmental influences heavily shape the gut microbiome in 2022 research, which subsequently affects outcomes of mental health significantly across various populations. External variables like diet and physical activity heavily influence microbial impact on mental well-being. [19]

Clark and Mach (2016) explored gut-microbiota-brain axis in athletes demonstrating exercise-induced stress behaviours tampering with gut microbiota. Research indicates people suffering from mental health issues often exhibit diminished alpha diversity within gut microbiota relative to those deemed healthy ($p = 0.002$). A higher *Firmicutes/Bacteroidetes* ratio correlates with improved mental well-being, whereas those beset by mental maladies frequently display an opposite trend. Specific microbial strains exhibit rather unusual neuroactive properties somewhat effectively in various studies conducted recently under lab conditions. [20]

Gamma-aminobutyric acid, a vital neurotransmitter that appears to be involved in downregulating stress responses under a variety of physiological situations, is produced by *Lactobacillus brevis.* Serotonin and other monoamines play a crucial role in the brain-gut-microbiome axis and are significant targets in the treatment of major depressive disorder. Emerging evidence intriguingly suggests gut microbiota diversity correlates with brain structure in various profoundly significant ways. [31]

Table 2: Gut Microbiota Composition Throughout the Life Span.[33]

Life Span	Composition

Neonatal	Low diversity and a relative dominance of the phyla *Proteobacteria* and *Actinobacteria*
Adult	Dominated by members of the *Bacteroidetes* and *Firmicutes* phyla
Old age	*Bacteroides* and *Firmicutes* are the dominant phyla Significant loss of diversity, especially in frail elderly

5. Knowledge Gaps and Future Research Directions

Despite substantial evidence linking gut microbiota to mental health, several critical knowledge gaps remain. While numerous studies have identified associations between dysbiosis and psychiatric disorders, the precise causal mechanisms are not yet fully understood. Future research should focus on delineating these mechanisms, particularly by identifying specific microbial strains and their metabolic byproducts that influence brain function.

Another important question is whether probiotic treatments have long-term benefits for mental health. Do they provide lasting improvements, or do their effects wear off over time? Additionally, can we develop personalized microbiome-based therapies tailored to individuals? Answering these questions is key to making these treatments more effective in clinical settings[29].

It’s also crucial to explore how gut microbiota change throughout life. Studies suggest that microbiome composition shifts at different ages (Gacesa et al., 2022; Zhao et al., 2015), but we need long-term research to track these changes and understand how they relate to mental health over time. Future studies should take a large-scale approach, involve diverse populations and use advanced sequencing and bioinformatics tools to unravel the complex relationship between gut health and the brain. [24]

“Another person’s stool samples can improve your health.”

Fecal microbiota transplantation has garnered considerable attention as a potentially efficacious method for restoring gut health by counteracting overgrowth of deleterious bacteria. Currently, it is used mainly in medical settings for treating stubborn *Clostridioides* difficile infections under close professional medical supervision. Someone swallows ’capsules containing faecal matter from their partner and sibling in a striking scene from a Netflix documentary amidst serious health warnings. FMT introduces beneficial microbes pretty quickly but also transmits super nasty pathogens like *Shiga toxin*-producing *E. coli,* which leads to severe illness suddenly. [18]

As Prof. Jane Foster, an expert on the gut-brain axis at McMaster University, Canada, explains, “Good heart health is good brain health, but we cannot discount the potential role of microbes in improving all of that.” She warns, though, that taking probiotics alone is not enough to change the gut microbiota. "It does not matter how many probiotics a person takes if their diet is mostly hotdogs," she says. "The diversity of your gut microbiome is driven by the diversity of your diet." [25]

Beyond diet, researchers are also looking at how urbanization and modern lifestyles affect gut bacteria and mental well-being. Zuo et al. (2018) highlight the need to explore how environmental and social factors shape the microbiome, which could lead to better public health strategies for improving mental health. [27]

Additionally, more comprehensive studies are needed to explore the influence of various environmental factors on gut microbiota and their subsequent effects on mental health. This includes examining the role of different dietary patterns, lifestyle choices, and the complex interplay between genetics and the microbiome. [26]

6. Conclusion

Research has uncovered a fascinating and complex connection between gut microbiota and mental health, suggesting that microbial-based therapies could play a role in treating neuropsychiatric disorders[30]. As this field continues to grow, it's crucial to bridge existing knowledge gaps to fully tap into the microbiome's potential for mental health care. Future studies must clarify mechanisms of influence pretty thoroughly and examine the impact of various environmental factors rather effectively. Psychological scientists occupy a singularly advantageous position from which they can substantially contribute quite readily to cutting-edge microbiological research involving psychological and microbial factors alongside vagal processes. [32]

References

1. Cryan, J.., & Dinan, T.. (2012). Mind-altering microorganisms: the impact of the gut microbiota on brain and behaviour. *Nature Reviews Neuroscience* , 13 , 701-712 . http://doi.org/10.1038/nrn3346
2. Červenka, I.., Agudelo, Leandro Z.., & Ruas, J.. (2017). Kynurenines: Tryptophan's metabolites in exercise, inflammation, and mental health. *Science* , 357 . http://doi.org/10.1126/science.aaf9794
3. Parker, Bianca J.., Wearsch, P.., Veloo, A.., & Rodriguez-Palacios, A.. (2020). The Genus Alistipes: Gut Bacteria With Emerging Implications to Inflammation, Cancer, and Mental Health. *Frontiers in Immunology* , 11 . http://doi.org/10.3389/fimmu.2020.00906
4. Lyte, M.. (2013). Microbial Endocrinology in the Microbiome-Gut-Brain Axis: How Bacterial Production and Utilization of Neurochemicals Influence Behavior. *PLoS Pathogens* , 9 . http://doi.org/10.1371/journal.ppat.1003726
5. Gomaa, E. Z. (2020). Human gut microbiota/microbiome in health and diseases: a review. *Antonie van Leeuwenhoek*, *113*(12), 2019–2040. https://doi.org/10.1007/s10482-020-01474-7
6. Bransfield, R. C., Mao, C., & Greenberg, R. (2024). Microbes and Mental Illness: Past, Present, and Future. In *Healthcare (Switzerland)* (Vol. 12, Issue 1). Multidisciplinary Digital Publishing Institute (MDPI). https://doi.org/10.3390/healthcare12010083
7. Reid, G. (2019). Disentangling what we know about microbes and mental health. *Frontiers in endocrinology*, *10*, 81.
8. Scotti E, Boué S, Sasso GL, et al. Exploring the microbiome in health and disease: Implications for toxicology. Toxicology Research and Application. 2017;1. doi:10.1177/2397847317741884
9. Smith, L. K., & Wissel, E. F. (2019). *Microbes and the Mind: How Bacteria Shape Affect, Neurological Processes, Cognition, Social Relationships, Development, and Pathology. Perspectives on Psychological Science, 14(3), 397–418.* doi:10.1177/1745691618809379

10. Cryan, J.., O'Riordan, Kenneth J.., Cowan, C.., Sandhu, K.., Bastiaanssen, T.., Boehme, Marcus., Codagnone, M.., Cussotto, S.., Fulling, Christine., Golubeva, A.., Guzzetta, K. E.., Jaggar, Minal., Long-Smith, C.., Lyte, J.., Martin, J. A.., Molinero-Perez, Alicia., Moloney, G.., Morelli, E.., Morillas, E.., O'Connor, Rory., Cruz-Pereira, Joana S.., Peterson, Veronica L.., Rea, K.., Ritz, N.., Sherwin, E.., Spichak, S.., Teichman, Emily M., Wouw, M. van de., Ventura-Silva, A.., Wallace-Fitzsimons, Shauna E., Hyland, N.., Clarke, G.., & Dinan, T.. (2019). The Microbiota-Gut-Brain Axis.. *Physiological reviews* , 99 4 , 1877-2013 . http://doi.org/10.1152/physrev.00018.2018
11. H.H. Shen, Microbes on the mind, Proc. Natl. Acad. Sci. U.S.A. 112 (30) 9143-9145, https://doi.org/10.1073/pnas.1509590112 (2015)
12. Misiak, B., Łoniewski, I., Marlicz, W., Frydecka, D., Szulc, A., Rudzki, L., & Samochowiec, J. (2020). The HPA axis dysregulation in severe mental illness: Can we shift the blame to gut microbiota? *Progress in Neuro-Psychopharmacology and Biological Psychiatry*, *102*, 109951. https://doi.org/10.1016/j.pnpbp.2020.109951
13. Galland, L.. (2014). The gut microbiome and the brain.. *Journal of medicinal food* , 17 12 , 1261-72 . http://doi.org/10.1089/jmf.2014.7000
14. Bischoff, S. C. (2011). 'Gut health': a new objective in medicine?. *BMC medicine*, *9*, 1-14.
15. Dinan, K., & Dinan, T. (2022). Antibiotics and mental health: The good, the bad and the ugly. *Journal of internal medicine*, *292*(6), 858-869.
16. van Andel, M., van Schoor, N. M., Korten, N. C., Heijboer, A. C., & Drent, M. L. (2022). Ghrelin, leptin and high-molecular-weight adiponectin in relation to depressive symptoms in older adults: Results from the Longitudinal Aging Study Amsterdam. Journal of Affective Disorders, 296, 103-110.
17. van Haeringen, M., Milaneschi, Y., Lamers, F., Penninx, B. W. J. H., & Jansen, R. (2023). Dissection of depression heterogeneity using proteomic clusters. *Psychological Medicine*, *53*(7), 2904–2912. doi:10.1017/S0033291721004888
18. Rajan, K. (2023). *This Book May Save Your Life: Everyday Health Hacks to Worry Less and Live Better*. Random House.
19. Montiel-Castro, A. J.., González-Cervantes, R.., Bravo-Ruiseco, Gabriela., & Pacheco-López, G.. (2013). The microbiota-gut-brain axis: neurobehavioral correlates, health and sociality. *Frontiers in Integrative Neuroscience* , 7 . http://doi.org/10.3389/fnint.2013.00070
20. Clark, A., & Mach, N. (2016). Exercise-induced stress behavior, gut-microbiota-brain axis and diet: a systematic review for athletes. *Journal of the International Society of Sports Nutrition*, *13*, 43. https://doi.org/10.1186/s12970-016-0155-6
21. Forsythe, P.., & Kunze, W.. (2012). Voices from within: gut microbes and the CNS. *Cellular and Molecular Life Sciences* , 70 , 55 - 69 . http://doi.org/10.1007/s00018-012-1028-z
22. Needham, Brittany D.., Funabashi, Masanori., Adame, M. D.., Wang, Zhuo., Boktor, Joseph C.., Haney, J.., Wu, Wei-Li., Rabut, Claire., Ladinsky, M.., Hwang, Son-Jong., Guo, Yumei., Zhu, Qiyun., Griffiths, J.., Knight, R.., Bjorkman, P.., Shapiro, Mikhail G.., Geschwind, D.., Holschneider, D.., Fischbach, M.., & Mazmanian, S.. (2022). A gut-derived metabolite alters brain activity and anxiety behaviour in mice. *Nature* , 602 , 647 - 653 . http://doi.org/10.1038/s41586-022-04396-8
23. Davis, N. (2023). Gut feelings: why drugs that nurture your microbes could be the future of mental health.

24. Breit, S.., Kupferberg, Aleksandra., Rogler, G.., & Hasler, G.. (2018). Vagus Nerve as Modulator of the Brain–Gut Axis in Psychiatric and Inflammatory Disorders. *Frontiers in Psychiatry* , 9 . http://doi.org/10.3389/fpsyt.2018.00044
25. Caputi, V.., & Giron, M.. (2018). Microbiome-Gut-Brain Axis and Toll-Like Receptors in Parkinson's Disease. *International Journal of Molecular Sciences* , 19 . http://doi.org/10.3390/ijms19061689
26. Clark, Allison., & Mach, N.. (2016). Exercise-induced stress behaviour, gut-microbiota-brain axis and diet: a systematic review for athletes. *Journal of the International Society of Sports Nutrition* , 13 . http://doi.org/10.1186/s12970-016-0155-6
27. Evrensel, A.., & Ceylan, M.. (2015). The Gut-Brain Axis: The Missing Link in Depression. *Clinical Psychopharmacology and Neuroscience* , 13 , 239 - 244 . http://doi.org/10.9758/cpn.2015.13.3.239
28. Clapp, M.., Aurora, Nadia., Herrera, Lindsey., Bhatia, M.., Wilen, Emily., & Wakefield, Sarah M.. (2017). Gut microbiota's effect on mental health: The gut-brain axis. *Clinics and Practice* , 7 . http://doi.org/10.4081/cp.2017.987
29. Ma, Qianquan., Xing, Changsheng., Long, Wenyong., Wang, Helen Y., Liu, Qing., & Wang, Rong-Fu. (2019). Impact of microbiota on central nervous system and neurological diseases: the gut-brain axis. *Journal of Neuroinflammation* , 16 . http://doi.org/10.1186/s12974-019-1434-3
30. Nota, M. H., Nicolas, S., O'Leary, O. F., & Nolan, Y. M. (2023). Outrunning a bad diet: interactions between exercise and a Western-style diet for adolescent mental health, metabolism and microbes. *Neuroscience & Biobehavioral Reviews*, *149*, 105147.
31. Gacesa, R., Kurilshikov, A., Vich Vila, A., Sinha, T., Klaassen, M. A., Bolte, L. A., ... & Weersma, R. K. (2022). Environmental factors shaping the gut microbiome in a Dutch population. *Nature*, *604*(7907), 732-739. http://doi.org/10.1038/s41586-022-04567-7
32. Dinan, T. G., Stilling, R. M., Stanton, C., & Cryan, J. F. (2015). Collective unconscious: how gut microbes shape human behavior. *Journal of psychiatric research*, *63*, 1-9.
33. Dinan, T. G., & Cryan, J. F. (2016). Microbes, Immunity, and Behavior: Psychoneuroimmunology Meets the Microbiome. *Neuropsychopharmacology*, *42*(1), 178-192. https://doi.org/10.1038/npp.2016.103

rebioin journal
OF BIOSCIENCES

“MICROBES AND MENTAL HEALTH: EXPLORING THE GUT-BRAIN AXIS AND MICROBIAL INFLUENCES ON COGNITIVE AND EMOTIONAL WELL-BEING.”

Plot no 977, GMS Road, near Balliwala Flyover, opposite Cubic Plaza,
Dehradun, Uttarakhand 248001

✉ admin@reboin.com
🌐 www.rebioin.com