International Journal on Science and Technology (IJSAT)
E-ISSN: 2229-7677 ● Website: www.ijsat.org ● Email: editor@ijsat.org

The Microbiome-Gut-Brain Axis: A Comprehensive Review of Its Role in Mental Health, Therapeutic Interventions, and Future Research Directions

Mr. M Bharath Bala

Research Assistant
Integrative Medical Research
Sri Manakula Vinayagar Medical College and Hospital

Abstract
The microbiome-gut-brain axis (MGBA) represents a complex, bidirectional communication system integrating neural, endocrine, immune, and metabolic pathways. Emerging evidence suggests that disruptions in gut microbial composition are closely associated with mental health disorders such as depression and anxiety, conditions that impose significant global health and economic burdens. This review synthesizes current knowledge on the mechanisms underlying MGBA communication, highlighting the roles of short-chain fatty acids, neurotransmitters, and immune mediators in shaping brain function. It further examines distinct microbial signatures identified in psychiatric disorders, emphasizing reduced microbial diversity and altered levels of key bacterial genera. Therapeutic approaches, including probiotics, psychobiotics, fecal microbiota transplantation (FMT), and dietary modulation, are critically evaluated for their efficacy, limitations, and translational potential. While preclinical and some clinical findings are promising, controversies regarding causality versus correlation, methodological inconsistencies, and translational hurdles remain unresolved. The review proposes a future research roadmap emphasizing standardized methodologies, large-scale longitudinal human studies, and the integration of artificial intelligence with advanced sequencing technologies.

Keywords: Microbiome-gut-brain axis, Mental health, Depression, Anxiety, Short-chain fatty acids, Probiotics, Fecal microbiota transplantation, Neuroinflammation

Introduction
The global prevalence of mental health disorders, such as depression and anxiety, presents an urgent public health challenge, imposing significant burdens on individuals, societies, and healthcare systems. According to epidemiological data, approximately one in eight people may experience a mental health problem, with depression and anxiety accounting for a substantial portion of the global burden of non-communicable diseases. These conditions can have a disabling effect on quality of life and incur significant economic costs due to lost productivity. Conventional treatments, while effective for many, are not universally successful, prompting a search for novel therapeutic targets.
This search has led to the re-emergence of a holistic view of human health, harkening back to 19th-

century beliefs that linked "corporeal disorder" and the "great abdominal brain" to mental state. Physicians of that era observed that digestive dysfunction was often associated with mood abnormalities, anxiety, and fatigue, and they posited that "nervous sympathy" connected the gastrointestinal system and the mind. Modern science now provides the mechanistic evidence for this historical concept through the study of the microbiome-gut-brain axis (MGBA). The MGBA represents a paradigm shift, viewing the gut's microbial ecosystem as a central regulator of mood, cognition, and emotional regulation. The purpose of this review is to provide an in-depth, expert-level synthesis of the current state of knowledge regarding the MGBA's role in mental health. We will elucidate the complex communication pathways, detail the specific microbial signatures associated with psychiatric disorders, and critically evaluate the efficacy and safety of emerging microbiome-based interventions. We will also confront the field's central controversies and outline a clear direction for future research.

2. Mechanisms of Communication Along the Gut-Brain Axis

The bidirectional communication between the gut and the brain is not mediated by a single pathway but by a complex, multi-layered system. Understanding these interconnected pathways is crucial for developing effective and targeted interventions. The gut microbiome acts as a dynamic interface with the host, influencing numerous physiological processes.

2.1. Neural Pathways: The Vagus Nerve and the Enteric Nervous System

The vagus nerve (VN) is the primary anatomical and functional link between the gut and the brain, consisting of approximately 80% afferent (gut-to-brain) and 20% efferent (brain-to-gut) fibers. This mixed-fiber structure enables it to act as a crucial sensor, transmitting a wide range of signals from the digestive system to the central nervous system, thereby influencing mood and emotional states. The VN is more than a passive conduit; it is a critical modulator that can be directly stimulated by microbial components and their metabolic products, influencing brain regions related to mood and emotion. This provides a rapid and direct mechanism for the gut to influence the brain. The communication is also reciprocal; the brain's response to stress can inhibit the VN, which has deleterious effects on the gastrointestinal tract and the microbiota, potentially creating a negative feedback loop that perpetuates pathological conditions[8].

2.2. Endocrine and Neuroendocrine Pathways

The hypothalamic-pituitary-adrenal (HPA) axis, the body's central stress response system, is directly modulated by the gut microbiome. Gut microbes alter the release of biologically active peptides from enteroendocrine cells, which in turn can affect HPA axis [6] activity and stress responses. This interaction is profoundly bidirectional. The brain's response to stressors, such as chronic social defeat or physical separation, can alter gut microbiota diversity and composition. These microbiota alterations, consistent with characteristics observed in depressed human patients, can then perpetuate brain changes, creating a self-reinforcing, pathogenic "vicious cycle" where a disrupted microbiome and neurological alterations sustain each other.

2.3. Immune and Inflammatory Pathways

An imbalanced gut microbiota, a state known as dysbiosis, can lead to chronic low-grade inflammation by modifying the balance of regulatory T-cells and cytokine production. This can compromise the intestinal barrier, a condition colloquially known as "leaky gut," allowing toxins, undigested food particles, and harmful microbes to enter the bloodstream. This is a crucial mechanistic link between gut health and neuroinflammation. When the intestinal barrier is compromised, inflammatory molecules can subsequently cross the blood-brain barrier (BBB), activating microglia, which are the resident immune cells of the central nervous system (CNS). This resulting neuroinflammation is increasingly recognized as a key driver of depression and other neurological disorders.

2.4. Metabolic Pathways: The Role of Microbial Metabolites

The gut microbiome functions as an "anaerobic bioreactor", programmed to synthesize molecules that direct the host's immune system and metabolism. It produces a vast array of neuroactive metabolites that directly influence brain function.

2.4.1. Short-Chain Fatty Acids (SCFAs)

SCFAs, such as butyrate, propionate, and acetate, are produced by the fermentation of resistant starches and dietary fiber by gut bacteria. These compounds are crucial for gut health and can traverse the blood-brain barrier. They exert their influence through two key mechanisms: inhibiting histone deacetylases (HDACs), which enhances gene transcription, and binding to specific receptors on enteroendocrine cells and neuroglial cells. Beyond their direct effects on cellular energy, SCFAs have demonstrated potent anti-inflammatory properties by inhibiting mitogen-activated protein kinase (MAPK) pathways and nuclear factor-kappaB (NF-kB), leading to a reduction in pro-inflammatory mediators. This action helps downregulate excessive neuroinflammatory responses and supports the integrity of the intestinal and blood-brain barriers, thereby indirectly influencing brain health and function.

2.4.2. Neurotransmitters and Precursors

Gut bacteria can produce neurotransmitters and their precursors, fundamentally impacting emotional regulation. It is estimated that over 90% of the body's serotonin is found within the gastrointestinal tract, and gut microbes directly influence its synthesis in enterochromaffin (EC) cells. Similarly, certain bacteria have the capacity to produce major neurotransmitters like gamma-aminobutyric acid (GABA) and dopamine, which are involved in emotional regulation. The metabolism of the amino acid tryptophan by the gut microbiota also plays a critical role, as tryptophan is a precursor to serotonin [16].

Table No. 1: Key Microbial Metabolites and Their Mechanisms of Action on the Brain

Metabolite/Compound	Origin	Key Mechanisms of Action
Short-Chain Fatty Acids	Microbial fermentation of dietary fiber (e.g., butyrate, acetate)	1. Crosses the blood-brain barrier to influence glial cells. 2. Exhibits potent anti-inflammatory effects by inhibiting pro-inflammatory pathways. 3. Influences neurogenesis and neuroplasticity. 4. Provides energy for colonocytes and regulates the intestinal barrier.
Serotonin (5-HT)	Synthesized in the gut's	1. Acts as a neurotransmitter and

	enterochromaffin (EC) cells, influenced by microbial action on tryptophan.	hormone. 2. Key role in regulating mood, sleep, appetite, and gut motility. 3. Microbes can directly influence their synthesis and release.
GABA	Produced by certain gut microbiota, including some strains of Lactobacillus and Bifidobacterium.	1. Acts as the primary inhibitory neurotransmitter in the CNS. 2. Plays a role in emotional regulation and stress response.
Lipopolysaccharides (LPS)	Structural components of Gram-negative bacteria.	1. If the intestinal barrier is compromised, LPS can enter the bloodstream. 2. Provides low-grade, tonic stimulation of the innate immune system. 3. Can lead to systemic and/or CNS inflammation, contributing to the pathogenesis of disorders.

3. Gut Microbiota Signatures in Mental Health Disorders

Recent studies using advanced techniques like metagenomic sequencing and metabolic analyses have provided compelling evidence that individuals with anxiety and depression have distinct microbial signatures compared to healthy controls. This research has gone beyond simple correlations to identify specific compositional differences that may contribute to psychological symptoms. For patients with major depressive disorder (MDD), a consistent finding is a reduction in overall microbial diversity. This reduced diversity is often associated with increased stress susceptibility and anxiety. Furthermore, individuals with MDD have been found to have lower levels of beneficial short-chain fatty acids [14] (SCFAs) like butyrate and acetate, which are crucial for mood regulation. Specific bacterial genera are also implicated. For example, some studies have found higher levels of Oscillibacter [17] and Alistipes in individuals with depression, while anxiety has been associated with elevated levels of inflammatory bacteria like Proteobacteria [17]. Conversely, beneficial bacteria, such as specific strains of Lactobacillus [15] and Bifidobacterium, have been shown to lessen anxiety and mood disorders, potentially by modulating stress-related responses and influencing serotonin [16] production. The Firmicutes to Bacteroidetes (F/B) ratio is also considered a marker of gut health, with imbalances linked to neuropsychiatric conditions. While research has focused primarily on bacteria, the field is moving toward a "pan-microbiome" concept, recognizing that other components of the microbial ecosystem, such as fungi, viruses, and archaea, may also play a crucial, yet understudied, role. Understanding the full spectrum of the microbiota and its interactions with the host is essential for developing comprehensive and effective interventions.

4. Emerging Microbiome-Based Therapeutic Interventions

The growing understanding of the MGBA has led to the development of novel therapeutic strategies that aim to restore a healthy microbial balance. These interventions represent a promising avenue for a new generation of mental health treatments that go beyond traditional pharmacology.

4.1. Probiotics and Psychobiotics

Probiotics are consumable microorganisms that promote gut microbiota balance and, in theory, can confer health benefits on the host, including benefits regarding brain and mental health. Preclinical and animal studies have provided considerable evidence that certain probiotic strains can modulate stress-related responses and alleviate depressive symptoms by inducing physiological and behavioral changes. However, the clinical evidence from human trials has been less consistent. Probiotic supplementation has shown "modest benefits" in some cases, but the results remain inconsistent across studies. This variability reflects the complexity of the human microbiome and the challenge of a one-size-fits-all approach, where a single probiotic strain may not be effective for all individuals due to their unique microbial profiles and environmental factors.

4.2. Fecal Microbiota Transplantation (FMT)

FMT, the infusion of fecal matter from a healthy donor into a patient's gut, is a more powerful intervention aimed at reconstituting the entire microbial ecosystem. Preclinical studies have provided compelling evidence for the causal role of the microbiome in mental disorders. For example, transferring microbiota from a healthy rat model to a depressive rat model "alleviated depressive symptoms," increased hippocampal neurotransmitters, and decreased inflammation, directly regulating the recipient's neurobiology and behavior.

FMT has also shown promise in clinical settings, with patients reporting improvements in gastrointestinal symptoms and overall quality of life. A key example of an ongoing effort to validate FMT as a mainstream therapeutic strategy is the multicenter, randomized, double-blind, placebo-controlled study identified by the clinical trial identifier NCT06692361 [21]. This study is evaluating the efficacy and safety of adjunctive FMT capsules in patients with major depressive disorder who exhibit a limited response to traditional antidepressant treatment. With an estimated completion in late 2026, the trial is designed to compare the effects of microbiota capsules against a placebo, using the Hamilton Depression Rating Scale (HAMD-17) as the primary outcome measure. This type of rigorous, large-scale clinical trial is crucial for establishing the long-term safety and efficacy of FMT and its potential to revolutionize psychiatric care.

4.3. Dietary and Lifestyle Modulation

Dietary choices and lifestyle habits are core components of the MGBA system. A balanced, fiber-rich, and plant-based diet can promote the growth of beneficial bacteria and the production of health-promoting SCFAs, thereby shaping the gut microbiome and indirectly influencing brain health. The "GAPS" concept, a theory that links mental and neurological disorders to an impaired digestive system, presents a compelling link between a gut-healing dietary protocol and improved psychological well-being. While the GAPS [13] protocol has many anecdotal success stories, its scientific research is still emerging. However, it underscores the potential for non-pharmacological interventions in mental healthcare by focusing on restoring gut integrity through diet, supplementation, and lifestyle changes.

Table No. 2: Summary of Therapeutic Interventions and Their Efficacy

Intervention	Proposed Mechanism	Key Findings & Status	Limitations & Controversies
Probiotics and Psychobiotics	Introduce beneficial microorganisms to balance gut flora and promote the production of neuroactive compounds.	Preclinical: Show a reduction in stress-related responses and alleviation of depressive symptoms in animal models. Clinical: Human trials have yielded inconsistent results, with modest benefits reported.	Efficacy is questionable and not universally effective. The lack of standardized protocols, strain variability, and individual microbial heterogeneity are major challenges.
Fecal Microbiota Transplantation (FMT)	Reconstitute the entire gut microbiota by transferring fecal matter from a healthy donor into a patient's gut.	Preclinical: FMT from healthy donors can alleviate depressive behaviors and restore hippocampal neurotransmitters in animal models, demonstrating a causal link. Clinical: Promising results in clinical settings, and an ongoing large-scale trial is evaluating its efficacy.	The field requires more research to validate long-term safety and efficacy, identify specific therapeutic strains, and develop targeted microbial modulation strategies. Regulatory hurdles and safety concerns remain.
Dietary and Lifestyle Modulation	Shape the gut microbiome by increasing beneficial bacteria and promoting the production of short-chain fatty acids.	A balanced, fiber-rich diet promotes a diverse and healthy gut microbiome. Emerging concepts link dietary interventions to improved psychological well-being.	These interventions are largely based on anecdotal success stories and require more rigorous scientific research to establish a definitive link.

5. Controversies, Challenges, and Future Directions

Despite the immense promise, the field of MGBA research faces significant controversies and challenges that must be addressed for it to mature into clinical practice.

5.1. The Causality Conundrum: Driver or Passenger?

The central debate in the field is whether gut dysbiosis [2] is a direct cause of mental illness or a consequence of the patient's lifestyle, pathology, or medication use. While animal studies have provided strong evidence for a causal link by showing that transferring microbiota from depressed humans or animals can induce depression-like behaviors in healthy recipients, human research, which is often cross-sectional, has struggled to definitively answer this question. The most probable scenario is a complex feedback loop. A stressful lifestyle or a pathological condition can induce gut dysbiosis [2], and that dysbiosis, in turn, can exacerbate mental health symptoms via inflammatory and metabolic pathways, creating a self-perpetuating cycle. The research should therefore focus on large-scale, longitudinal studies to map this reciprocal relationship over time and more precisely determine the directionality of the MGBA.

5.2. Methodological Inconsistencies

The field is hindered by a lack of standardized microbiome assessment techniques and significant inter-individual variability. The differences in gut microbiome composition among individuals, which are influenced by genetic, environmental, and dietary factors, make it difficult to compare findings across different studies. This challenge is perfectly illustrated by conflicting results from germ-free mice studies, where one group found social deficits and another found the mice to be more social, demonstrating how slight differences in experimental design or environment can produce contradictory findings.

5.3. Translational Hurdles

There is a significant chasm between promising findings in controlled animal models and their translation to diverse human populations. The biological differences between species and the immense complexity of human lifestyles, including diet, medication, and environmental exposures, make direct application of animal data challenging and highlight the need for more human-centric research and clinical trials.

5.4. A Roadmap for Future Research

To overcome these challenges, future research must be comprehensive and collaborative. The field needs to prioritize standardized methods for microbiome assessment to allow for robust comparison across studies. The future of microbiome therapy lies in personalized medicine, tailoring interventions to an individual's unique microbial profile. This will require the development of novel microbial biomarkers for diagnosis and treatment monitoring. Furthermore, advances in sequencing technologies, such as third-generation sequencing platforms, and the application of artificial intelligence and machine learning will be critical for deciphering complex microbial-host interactions and identifying core microbiome patterns that can be targeted therapeutically.

Table No. 3: Summary of Major Controversies and Research Gaps

Controversy/Challenge	Description	Future Research Priorities
Causality vs. Correlation	The central debate is whether gut dysbiosis is a cause or a consequence of mental illness. Cross-sectional human studies cannot establish directionality, while animal models suggest a causal link.	The field requires more rigorous, large-scale longitudinal studies in human populations to determine the temporal relationship between microbial changes and disease onset.
Methodological Inconsistencies	There is a lack of standardized microbiome assessment techniques and significant inter-individual variability, making it difficult to compare findings across different studies and	Research efforts must focus on standardizing protocols for microbiome analysis and developing advanced bioinformatics tools to account for the high degree of heterogeneity among individuals.

	leading to conflicting results.	
Translational Hurdles	Translating promising findings from controlled animal models to diverse human populations is challenging due to species-specific biological differences and the complexity of human lifestyles.	A greater focus on well-designed human clinical trials and integrated research involving microbiology, neuroscience, and clinical psychiatry is needed to fully understand the therapeutic benefits of microbiome-focused treatments.
Therapeutic Optimization	The efficacy of interventions like probiotics is inconsistent, and the specific mechanisms by which they influence mental health are not fully understood.	Future research must identify specific therapeutic microbial strains and develop personalized, microbiome-based therapies that tailor interventions to an individual's unique microbial profile. This will require the development of novel microbial biomarkers.

Publishing and Ethical Considerations
This review, with its focus on mechanistic and cause-and-effect studies, is well-suited for submission to specialized journals that are at the forefront of this field. Appropriate venues include the Gut-Brain Axis section of Frontiers in Neuroscience, Gut Microbes, or Beneficial Microbes. These journals are open access, have a multidisciplinary scope, and actively publish cutting-edge research and reviews on the intricate relationship between the gut microbiota and host health.

Conclusion

The MGBA is a robust and increasingly understood pathway linking the gut's microbial ecosystem to the central nervous system. This bidirectional communication, mediated by neural, endocrine, immune, and metabolic signaling, provides a compelling biological basis for the profound link between gut health and mental well-being. The transformative potential of microbiome-targeted therapies in revolutionizing mental healthcare is immense. The success of interventions like FMT in preclinical models and ongoing clinical trials suggests a future where treatments are not only more effective but also more personalized and holistic. To bridge the remaining gaps in knowledge, collaborative, interdisciplinary research is critical. By addressing the fundamental controversies and leveraging technological advancements, the field is poised to usher in a new era of mental healthcare, moving from the promise of the gut-brain axis to its full clinical realization.

References

1. The gut microbiome on mental health [Internet]. National Library of Medicine.. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC11865252/
2. The gut microbiota influences emotional equilibrium by regulating neural circuits and modulating the release of neurotransmitters within the central nervous system, thus providing novel insights into the biological foundations of mood disorders [Internet]. Frontiers in Immunology.. Available from:

https://www.frontiersin.org/journals/immunology/articles/10.3389/fimmu.2024.1416961/full
3. The microbiota-gut-brain axis: A new direction in research on depression [Internet]. ResearchGate.. Available from: https://www.researchgate.net/publication/352911910_The_Microbiota-Gut-Brain_Axis_A_New_Direction_in_Research_on_Depression
4. The Gut-Brain Axis in the 19th Century [Internet]. MDPI.. Available from: https://www.mdpi.com/2076-0817/11/12/1540
5. The gut microbiome on mental health [Internet]. National Library of Medicine.. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC12007925/
6. The Gut-Brain Axis [Internet]. National Library of Medicine.. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC6469458/
7. The brain-gut-microbiome axis (BGMA) has emerged as a central regulator of neural health and disease [Internet]. International Journal of Health Sciences. Available from: https://intjhs.org/brain-gut-microbiome-axis-in-neurodegeneration-current-controversies-and-future-research-directions/
8. The vagus nerve [8] in the microbiota-gut-brain axis [Internet]. Frontiers in Neuroscience [29].. Available from:
9. Direct and indirect mechanisms by which the gut microbiota influence host serotonin [16] systems [Internet]. ResearchGate.. Available from:
10. The vagus nerve [8] represents the main component of the parasympathetic nervous system [Internet]. Frontiers in Psychiatry.. Available from:
11. The human gut microbiome impacts human brain health in numerous ways [Internet]. National Library of Medicine.. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC4259177/
12. Short-chain fatty acids, of interest for their potential health benefits, are influenced by a fiber- and plant-based diet [Internet]. MDPI.. Available from: https://www.mdpi.com/1422-0067/24/20/15094
13. Gaps Gut And Psychology Syndrome [Internet]. Primary Health Tasmania.. Available from: https://ftp.primaryhealthtas.com.au/Resources/UBpzEa/271009/GapsGutAndPsychologySyndrome.pdf
14. Short-chain fatty acids (SCFAs) exert many nutritional benefits on both physiological and pathological processes [Internet]. International Journal of Food Science & Technology.. Available from: https://academic.oup.com/ijfst/article/59/9/5902/7911641
15. Serotonin, as a neurotransmitter, plays a key role in regulating mood, sleep, appetite, and various physiological processes [Internet]. ResearchGate.. Available from: https://www.researchgate.net/publication/377827304_Serotonin_The_Link_between_Gut_Microbiome_and_Brain
16. Short-chain fatty acids, of interest for their potential health benefits, are influenced by a fiber- and plant-based diet [Internet]. MDPI.. Available from: https://www.mdpi.com/1422-0067/24/20/15094
17. Gut microbiota and depression [Internet]. National Library of Medicine.. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC10146621/
18. What's next in microbiome research? [Internet]. Abcam.. Available from: https://www.abcam.com/en-us/stories/articles/whats-next-in-microbiome-research
19. Fecal microbiota transplantation as a novel therapeutic strategy for depression [Internet]. National Library of Medicine.. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC11231080/
20. Fecal microbiota transplantation from healthy rats to depressive rats [Internet]. National Library of Medicine.. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC9239139/

21. Assessment of the Efficacy and Safety of Fecal Microbiota Transplantation [19] [Internet]. ClinicalTrials.gov.. Available from:
22. The brain-gut-microbiome axis (BGMA) has emerged as a central regulator of neural health and disease [Internet]. International Journal of Health Sciences. Available from: https://intjhs.org/brain-gut-microbiome-axis-in-neurodegeneration-current-controversies-and-future-research-directions/
23. The gut microbiome on mental health [Internet]. National Library of Medicine.. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC12007925/
24. What's next in microbiome research? [Internet]. Abcam.. Available from: https://www.abcam.com/en-us/stories/articles/whats-next-in-microbiome-research
25. What's next in microbiome research? [Internet]. Abcam.. Available from: https://www.abcam.com/en-us/stories/articles/whats-next-in-microbiome-research
26. COPE guidelines on publication ethics [Internet]. Norwegian University of Science and Technology.. Available from: https://www.ntnu.edu/documents/140096/1275971792/COPEguidelines.pdf/69279e5d-f81b-4628-a4a1-e6bf88e31d22
27. Scifiniti publication ethics and integrity guidelines [Internet]. Scifiniti.. Available from: https://scifiniti.com/publication-ethics-and-integrity-guidelines
28. Wiley's ethics guidelines [Internet]. Wiley.. Available from: https://authorservices.wiley.com/ethics-guidelines/index.html
29. Scifiniti publication ethics and integrity guidelines [Internet]. Scifiniti.. Available from: https://scifiniti.com/publication-ethics-and-integrity-guidelines
30. COPE guidelines on publication ethics [Internet]. Norwegian University of Science and Technology.. Available from: https://www.ntnu.edu/documents/140096/1275971792/COPEguidelines.pdf/69279e5d-f81b-4628-a4a1-e6bf88e31d22
31. Elsevier publishing ethics [Internet]. Elsevier.. Available from: https://www.elsevier.com/about/policies-and-standards/publishing-ethics
32. Frontiers in Neuroscience [29], Gut-Brain Axis section [Internet]. Frontiers Media.. Available from:
33. Gut Microbiome journal, guide for authors [Internet]. Cambridge University Press.. Available from: https://www.cambridge.org/core/journals/gut-microbiome/information/instructions-authors
34. Gut Microbes [31] journal [Internet]. Taylor & Francis.. Available from:
35. Beneficial Microbes [32] journal [Internet]. Brill.. Available from:
36. Academic journals for microbiome review articles [Internet]. Google.. Available from: https://www.google.com/search?q=academic+journals+for+microbiome+review+articles