Novel Research in Microbiology Journal (2024), 8(2): 2339-2353

(Print) (ISSN 2537-0286)
(Online) (ISSN 2537-0294)
https://nrmj.journals.ekb.eg/

Review Article

DOI: 10.21608/NRMJ.2024.273319.1479

From gut to brain: Deciphering the impact of gut microbiota on neurological health

Gopinath R.; Arundadhi M.; Dhanasezhian A.; Thangam G. Sucila*

Department of Microbiology, Government Theni Medical College, Theni, Tamil Nadu-625512, India

*Corresponding author E-mail: drgsucilamicro@gmail.com

Received: 28 February, 2024; Accepted: 20 March, 2024; Published online: 22 March, 2024

Abstract

The Gut-Brain Axis is a complex and fascinating concept elucidating the two-way communication between gut microbiota and the central nervous system, encompassing diverse mechanisms with profound implications on neurological health. Situated in the gastrointestinal tract, the gut microbiota, a diverse bacterial community, which communicates with the brain through various processes, including neurotransmitter and neuropeptide synthesis, immune system modulation, and involvement of the vagus nerve. These interactions not only impact digestion but also influence emotions, cognition, and behavior. Recent research has revealed the significant influence of gut microbiota on the neurological health, establishing connections between alterations in the gut microbiota composition and the prevailing conditions such as depression and neurodegenerative diseases. This understanding sheds new light on the pathophysiology of neurological disorders, marking the gut-brain axis as an exciting frontier in neuroscience and medicine. The aims of this study were to investigate and elucidate the intricate interplay between the gut microbiota and neurological health, and exploring the mechanisms of communication along the gut-brain axis. As research progresses, the potential for groundbreaking strategies to prevent and treat the neurological disorders becomes increasingly apparent. This comprehensive review delves into the nuanced world of the gut-brain axis, providing insights into the intricate relationship between the gut and the brain. Additionally, this review delves into potential therapeutic implications, exploring the use of probiotics, prebiotics, and dietary interventions to modulate gut microbiota for enhancement of the neurological well-being.

Keywords: Gut-brain axis, Gut microbiota, Vagus nerve, Depression, Neurological health

1. Introduction

The gut-brain axis is a complex and dynamic network that connects the gastrointestinal system with the central nervous system. It is a bidirectional communication system that connects the brain and the spinal cord to the enteric nerve system of the gastrointestinal tract (Wang and Wang, 2016). The gut, its microbiota, the immune system, and the endocrine system are all involved in this communication network (El Aidy *et al*., 2015). The gut microbiota and its impact on the gut-brain axis can vary substantially between individuals. Genetics, diet, and lifestyle all contribute to the individual's gut microbiota's unique makeup and function, which affects the gut-brain axis functions in each person (Ma *et al*., 2019). The vagus nerve, which sends bidirectional signals between the gut and the brain, provides direct connections between the two. The brain receives information about the gastrointestinal conditions such as nutrient absorption, gut motility, and inflammation for processing (Kuwahara *et al*., 2020). The gut produces neurotransmitters such as serotonin and gamma-aminobutyric acid (GABA), which are involved in mood control and cognitive function. These neurotransmitters have the ability to alter the mood and the emotions as well as the brain function (Dicks, 2022). Ghrelin and leptin are gut hormones that regulate appetite, satiety, and energy balance. These hormones can also have an effect on the brain functions such as appetite and body weight regulation (Doroszkiewicz *et al*., 2021). Emerging research suggests that the gut microbiota regulates mood and may influence the prevailing conditions such as depression, anxiety, and stress (Chen *et al*., 2021). Dysbiosis, or an imbalance in the gut microbiota, has been linked to the neurological disorders like Alzheimer's, Parkinson's, and multiple sclerosis (Liu *et al*., 2020). The gut microbiota is essential for immune system training and modulation. It aids the immune system in distinguishing between infections and helpful microorganisms. A disruption in the gut microbiota can cause chronic inflammation, which has been linked to a number of disorders, including those affecting the brain (Ding *et al*., 2020).

The gut-brain axis allows for continuous communication and synchronization between the gut and the brain, and regulating a variety of physiological and psychological processes (Mukhtar *et al*., 2019). Several researches have revealed that gut microbiota has a substantial impact on many areas of the neurological health, including cognitive function, mood control, and even neurodegenerative diseases. In the context of neurodegenerative diseases, these researches have uncovered the intriguing connections between alterations in the gut microbiota and the progression of conditions such as Alzheimer's and Parkinson's disease (Bistoletti *et al*., 2020; Maiuolo *et al*., 2021). Understanding that the gut-brain axis has implications on the therapeutic approaches, which target the gut microbiota, nutrition, and lifestyle to promote the gastrointestinal and the neurological health. This involves using probiotics and prebiotics, making dietary modifications, transplanting fecal microbiota, and developing specific drugs to control the gut microbiota. Some drugs can affect the gut-brain axis. The antibiotics, for example, may upset the balance of the gut microbiota, potentially harming the brain health (Cammarota *et al*., 2014). This interaction emphasizes the importance of gaining a thorough grasp of how these drugs may affect this axis. This in-depth examination examines the present level of knowledge and addressing the complex relationship between gut microbiota and neurological health. The objective of the study was to analyze the recent research findings that highlight the significant influence of the gut microbiota on the neurological disorders, thus contributing to a deeper understanding of the pathophysiology of the various conditions related to the central nervous system.

2. Composition of the human gut microbiota

The types and quantities of bacteria that live in the gastrointestinal tract, which includes the stomach, small intestine, and colon, are referred to as gut microbiota composition (Cryan *et al*., 2019). The gut microbiota is a rich ecosystem that contains a wide range of microorganisms such as bacteria, viruses, fungi, and archaea (Kandpal *et al*., 2022). A healthy gut microbiota is diverse, which means that it contains a wide range of bacterial species. This variety is linked to an enhanced overall health. Bacteria are the most prevalent and well-studied microorganisms in the gastrointestinal tract. There are thousands of different bacterial species, with the Firmicutes and the Bacteroidetes being the most common (Kaur *et al*., 2019). However, the precise composition varies from person to person. The makeup of the gut microbiota varies greatly. Genetics, diet, environment, age, and numerous lifestyle factors all have a role (Oriach *et al*., 2016). This means that no two people have the same gut microbiota.

Maintaining health requires a stable and resilient gut microbiota. However, several conditions such as antibiotics, illness, and/or a bad diet can upset this delicate equilibrium. While there is an individual variance, several bacterial species are found in the majority of the healthy people. These are frequently referred to as "core microbiota" (Torres-Fuentes *et al*., 2017). The gut microbiota is dominated by stringent anaerobes, which outnumber the facultative anaerobes and the aerobes by a factor of 100 (Ghanei *et al*., 2019). Estimates of the number of bacterial species present in the human gut vary greatly between the different researches; however, it is largely acknowledged that people harbor more than 1000 microbial, species-level phylotypes (Clapp *et al*., 2017). Although the proportional ratios of these phyla may vary, but the Bacteroidetes and the Firmicutes are conserved in almost all people (Mendes *et al*., 2021). Bacterial cells are scattered irregularly over the length of the gut. The number of bacteria present can range from 10 to 10^3 bacteria/ g of stomach and duodenal contents, 10^4 to 10^7 bacteria/ g in the small intestine, and to 10^{11} to 10^{12} bacteria/ g in the large intestine (Suganya and Koo, 2020). Furthermore, the microbial community makeup changes between these regions, with distinct bacterial species prevalent in the small intestine and colon. Understanding the makeup and variety of the gut microbiota is an important element of microbiota science study. It has far-reaching ramifications for the overall health and has led to the development of treatment techniques to control and optimize the gut microbiota composition.

3. Importance of the neurological health

The total well-being and proper functioning of the nervous system, which includes the brain, spinal cord, and peripheral nerves, is referred to as neurological health (Defaye *et al*., 2020). The nervous system is a complicated and crucial element of the human body, governing everything from fundamental reflexes to higher cognitive activities. The brain is the major nervous system component in charge of the cognitive functions, emotions, and sensory perception (Oroojzadeh *et al*., 2022). Maintaining strong neurological health is critical for the overall wellness. Many neurological illnesses can be avoided or postponed by making healthy lifestyle choices. Alzheimer's disease, Parkinson's disease, and stroke are examples of such illnesses (Roe, 2022). Maintaining cognitive function and memory is an important feature of the neurological health, especially as people get older. Puzzles, reading, and acquiring new abilities are all activities that can assist in boosting cognitive well-being. The management and treatments of neurological illnesses are also part of neurological health. Chronic illnesses such as epilepsy and multiple sclerosis, as well as acute disorders such as traumatic brain traumas, are examples of these (Mitrea *et al*., 2022). The involvement of gut microbiota in neurological health is a new and fast-developing area of study. There is still much to learn about the precise processes through which the gut microbiota influences the neurological health. Nonetheless, the gut-brain axis is an interesting area of research, and its potential consequences on the neurological health have important significance for the future neurology and psychiatry treatments and interventions (Benakis *et al*., 2020).

4. Pathways of communication between the gut and the gut-brain axis

Gut-brain microbiota axis is a complex bidirectional communication system that connects the gut, its microbiota, and the central neurological system (*i.e*., brain and spinal cord) (Zhu *et al*., 2017). This bidirectional communication is critical in maintaining the overall health and well-being. It is intimately related to the mood and the emotional well-being. The gut microbiota can create neuroactive chemicals that influence memory, learning, and other cognitive functions, resulting in cognitive deficits and possibly contributing to neurodegenerative illnesses (Keightley *et al*., 2015). Obesity and metabolic problems can result from communication dysfunctions (Sajdel-Sulkowska and Zabielski, 2013). This axis is important in influencing several physiological and psychological processes, and its importance has grown in the recent years. Multiple communication routes, including neurological, endocrine and immunological signaling, are involved in the microbiota gut-brain axis (Silva *et al*., 2020). The different types of communication pathways have been listed in Table (1).

5. Role of gut microbiota in the neurological health

5.1. Cognitive function

The gut-brain axis plays a crucial role in improving the cognitive function as the gut microbiota can influence the production and regulation of several neurotransmitters, such as serotonin, dopamine, and GABA (Manderino *et al*., 2017). These neurotransmitters are crucial for controlling the mood, and they also have a big impact on the cognitive performance (Socała *et al*., 2021). Serotonin, for instance, has been shown to affect the memory and learning. Chronic inflammation can result from dysbiosis or an imbalance in the gut microbiota. The serotonin produced in the gut can influence the mood and behavior. Changes in gut serotonin levels have been linked to conditions like irritable bowel syndrome (IBS) and may contribute to the bidirectional relationship between the gut health and the mental health (Margolis *et al*., 2021). Understanding the role of serotonin in the gut-brain axis provides insights into how the gastrointestinal health can impact the mental well-being and vice versa. This complex interplay emphasizes the holistic nature of health, recognizing the interconnectedness of the various body systems (Serra *et al*., 2019). Alzheimer's disease and other disorders that impair cognitive function have been connected to chronic inflammation (De la Fuente, 2021). By regulating the systemic inflammation, the gut-brain axis helps to maintaining the cognitive function. The gut bacteria create several metabolites such as butyrate and other short-chain fatty acids (SCFAs) (Dalile *et al*., 2019). SCFAs can improve the cognitive function and have neuroprotective and anti-inflammatory properties. Particularly butyrate has been demonstrated to support the cognitive health (Majumdar *et al*., 2023). The blood-brain barrier; a barrier that keeps the bloodstream and brain apart can be affected by the gut-brain axis (Raimondi *et al*., 2020). Antioxidants produced by certain gut bacteria can shield the brain tissue from the oxidative damage. These antioxidant properties are crucial for maintaining the cognitive health because the oxidative stress can cause cognitive impairment and neurodegenerative diseases (Gwak and Chang, 2021). The generation of neuroactive chemicals and a diverse and well-balanced gut flora has been shown to have neuroprotective effects on the brain (Liang *et al*., 2018). These benefits may provide protection against neurodegenerative illnesses and cognitive decline (Neri *et al*., 2023). Through a variety of processes, including neurotransmitter regulation, inflammatory control, and the delivery of vital nutrients, the gut-brain axis affects the cognitive performance (Agustí *et al*., 2018). Better cognitive health and general brain function can be achieved by supporting the gut-brain axis and keeping the gut microbiota in a healthy state (Wiley *et al*., 2017).

Table 1: Different types of communication pathways

Pathway	Features	References
Neural pathways	• The vagus nerve, which connects the gut and the brain, is critical in bidirectional signal transmission. • Data concerning gut circumstances, such as nutrient absorption and gut motility, is transmitted to the brain for processing.	(Han *et al*., 2022)
Neurotransmitters	• The gut microbiota can create and regulate the creation of neurotransmitters such as serotonin, dopamine, and gamma-aminobutyric acid (GABA), which are crucial for mood regulation and cognitive function. • These neurotransmitters can influence mood, emotions, and brain function.	(LaGreca *et al*., 2021)
Hormones	• The gut generates hormones that control hunger, satiety, and metabolism. • Hormones such as ghrelin and leptin regulate food intake and body weight, and they can have an effect on how the brain controls these processes.	(Pizarroso *et al*., 2021)
Cytokines and immune signaling	• Gut microorganisms and their metabolites have the potential to influence the immune system, resulting in the creation of cytokines and immunological responses that affect the brain. • Gut inflammation can have an effect on systemic inflammation and brain function.	(Agirman *et al*., 2021)
Microbial metabolites	• Metabolites produced by gut bacteria include short-chain fatty acids (SCFAs) such as butyrate. • These metabolites have the potential to enter the bloodstream and impact brain function and overall health.	(O'Riordan *et al*.,2022)

5.2. Mood regulation

The gut-brain axis significantly influences the emotional health and mood. Distortions in the neurotransmitter levels resulting from dysbiosis of the gut microbiota can impact the mood. Hormones such as leptin and ghrelin, which influence the sensations of hunger, fullness, and general well-being, can alter the human mood (Sun *et al*., 2020). Leptin is often referred to as the "satiety hormone" because it signals to the brain that the body has enough energy stores, thereby promoting a feeling of fullness and reducing appetite. Meanwhile, Ghrelin, known as the "hunger hormone," that stimulates the appetite and promotes the food intake. Ghrelin levels typically rise before meals and decrease after eating (Woo and Alenghat, 2022). A healthy gut microbiota and appropriate communication along the gut-brain axis can assist in managing the stress and its impact on the mood, which in turn affects the body's stress response (Foster *et al*., 2017). The expression of genes involved in the emotional regulation and the generation of stress hormones can both be influenced by the gut microbiota (Bear *et al*., 2021). Anxiety and sadness have been connected to dysbiosis in the gut microbiota (Petra *et al*., 2015).

5.3. Neurodegenerative diseases

Emerging research suggests a strong connection between the gut microbiota and the neurodegenerative diseases (Ghaisas *et al*., 2016). It is possible that the pathophysiology of several diseases like Alzheimer's and Parkinson's involves the gut-brain axis. Numerous neurodegenerative illnesses are influenced by chronic inflammation in their early stages (Chu *et al*., 2021; Sun *et al*., 2021). The systemic inflammation can be controlled by a healthy gut microbiota and efficient communication along the gut-brain axis (Louwies *et al*., 2020). Thus, there may be a decrease in the inflammatory load on the brain and a decreased chance of developing neurodegenerative diseases. Due to their neuroprotective properties, the SCFAs may be able to prevent the neurodegenerative illnesses (Moțățăianu *et al*., 2023). Neurotransmitters such as dopamine and serotonin can be produced and balanced *via* the gut-brain axis (Qian *et al*., 2022). Sustaining a robust gut-brain axis may aid in modulation of these neurotransmitters and mitigate the likelihood of several neurodegenerative disorders associated with mood (Yuan *et al*., 2023). Antioxidants produced by some gut bacteria have the ability to shield the brain tissue from oxidative stress, which is a major cause of neurodegenerative illnesses (Dumitrescu *et al*., 2018). These antioxidants may aid in preventing or delaying the onset of such illnesses by lowering the oxidative stress.

6. Therapeutic implications of the gut-brain axis

Gaining knowledge of the gut-brain axis has made the therapeutic approaches more feasible (Quigley, 2005). Altering the gut microbiota and brain communication, lifestyle adjustments, dietary adjustments, and the use of probiotics and prebiotics can help to treat these neurological conditions (Thangaleela *et al*., 2022). Personalized therapies are emerging as a result of our growing understanding of the unique characteristics of the gut-brain axis. The goal of precision medicine techniques is to customize the interventions to the person's particular genetic makeup, lifestyle choices, and gut microbiota composition (Evrensel and Tarhan, 2021). It is noteworthy that although the therapeutic implications of the gut-brain axis hold great promise, further study is necessary to confirm the safety and effectiveness of many of these approaches. Some of these potential approaches include:

6.1. Probiotics

Probiotics are live microorganisms, usually good bacteria that are taken orally to support the preservation or restoration of the normal gut microbiota balance (Kesika *et al*., 2021). Probiotics may enhance the gut health and thus have an impact on the gut-brain axis by encouraging the growth of beneficial bacteria (Westfall *et al*., 2017). Certain probiotic strains have the capacity to create mood-regulating neurotransmitters like GABA and serotonin. Additionally, they have anti-inflammatory properties that aid in lowering the long-term intestinal inflammation (Dahiya and Nigam, 2022). These probiotics may be advantageous to the general well-being and may have an effect on the brain health, since high levels of inflammation are associated with a number of neurological disorders.

6.2. Prebiotics

Prebiotics are indigestible dietary fibres and substances that nourish the good gut flora (Lasrado and Rai, 2022). They aid in promoting the development and activity of particular good bacteria in the digestive system by acting as a source of food for these bacteria (Hyland and Stanton, 2023). This may result in a more favorable makeup of the gut microbiota, which will benefit the gut-brain axis. Hormones that control hunger and weight, such as ghrelin and leptin, can be influenced by prebiotics (Joshi *et al*., 2018). Prebiotics can lower the risk of several gut-related problems that may impact the general well-being and the gut-brain axis.

6.3. Diet

In terms of the therapeutic implications of the gut-brain axis, diet is very important. Foods have an impact on the composition of gut microbiota, metabolite synthesis, and overall gut health, all of which are related to the brain function and mental health (Sandhu *et al*., 2017). A diet rich in fiber from whole grains, legumes, fruits, and vegetables encourages the development of good gut bacteria and ads to the diversity of the gut microbiota. Prebiotic fiber feeds the good bacteria that have a beneficial effect on the gut-brain axis. Consuming foods high in probiotics, such as kefir, sauerkraut, kimchi, and yogurt, can help the gut to become colonized with healthy living microorganisms (Barber *et al*., 2021). Berries, dark chocolate, tea, and red wine are foods high in polyphenols, which have anti-inflammatory and antioxidant properties (Brewer-Smyth, 2022). They can have a good impact on the gut-brain axis by lowering the inflammation and oxidative stress, which are linked to a variety of brain illnesses. Omega-3 fatty acids, which can be found in fatty fish such as salmon, walnuts, and flaxseeds, have neuro-protective properties (Ghosh, 2021). An anti-inflammatory diet low in processed foods, sweets, and saturated fats can help to lower the systemic inflammation, which benefits both the gut and the brain health (Berding *et al*., 2021a).The Mediterranean diet, which is high in fruits, vegetables, olive oil, and seafood, has been linked to a lower incidence of cognitive decline and mood disorders (Ağagündüz *et al*., 2023). Fasting and intermittent fasting have been demonstrated to improve the gut health and the gut-brain axis. Hydration is critical for the gut health as well as the overall body function (Berding *et al*., 2021b). These dietary recommendations may have therapeutic implications for maintaining a healthy gut-brain axis and promoting the mental and neurological health.

6.4. Lifestyle

Lifestyle decisions can have a significant influence on the gut-brain axis and its therapeutic implications on the overall health (Donoso *et al*., 2023). Regular exercise has been demonstrated to have a favorable effect on the gut-brain axis. Chronic stress can alter the gut-brain axis, causing gastrointestinal difficulties as well as mental health disorders. Proper sleep is required for a healthy gut-brain axis (Skonieczna-Żydecka *et al*., 2018). Sleep disruptions can affect the composition of the gut microbiota and increase the risk of mood disorders. Individuals can actively support the gut-brain axis and improve the general well-being by making beneficial lifestyle choices. These options are frequently used in conjunction with dietary and therapeutic interventions, and they can have a substantial impact on the prevention and management of the gut-related and neurological diseases (Naveed *et al*., 2021).

6.5. Fecal microbiota transplantation (FMT)

Fecal microbiota transplantation (FMT), often known as fecal transplant, is a medical treatment that involves transplanting of fecal materials having a healthy gut microbiota from a healthy donor into the gastrointestinal tract of a recipient (Hu *et al*., 2022). FMT offers therapeutic potential for the gut-brain axis and has received much interest in the gastrointestinal and neurological medicine (Zhu *et al*., 2023). FMT is generally used to restore the healthy gut microbiota in people who have gut dysbiosis, such as those with *Clostridium difficile* infection, Inflammatory bowel disease (IBD), and/ or Irritable bowel syndrome (IBS) (Limas-Solano *et al*., 2020). FMT may help improve the gut health by re-establishing a healthy gut microbiota, and hence regulate the gut-brain axis. It has the potential to introduce the beneficial gut bacteria into the recipient's gut. These bacteria may create metabolites with anti-inflammatory and neuroprotective properties, such as SCFAs. FMT is a tailored treatment, therefore choosing an appropriate donor is critical (Hillestad *et al*., 2022). The goal is to pair the recipient with a healthy donor whose gut microbiota makeup promotes the gut health and well-being. This tailored approach has the potential to improve the therapeutic effects on the gut-brain axis.

6.6. Targeted medications

In the study of the gut-brain axis, targeted drugs are a new area of research and development, which are intended to target and alter the gut microbiota or their communication with the brain in order to treat a variety of health conditions (Leprun and Clarke, 2019). Table (2) shows a list of some of the most important prospects of the tailored therapy.

Table 2: Types of target medications influencing the gut-brain axis

Medicine	Features	References
Psychobiotics	Psychobiotics are live microorganisms, similar to probiotics that have the ability to influence brain function and mental wellness. They are chosen for their capacity to generate neuroactive chemicals, impact neurotransmitter synthesis, and reduce inflammation.	(Kavvadia *et al*., 2017)
Microbial metabolite modulators	To alter the gut-brain axis, medications that target specific microbial metabolites, such as SCFAs or neurotransmitter precursors, can be employed. These drugs are designed to control the levels of metabolites that affect mood, cognitive function, and brain health.	(Van de Wouw *et al*., 2017)
Gut barrier enhancers	Medication that targets specific microbial metabolites, such as SCFAs or neurotransmitter precursors, can be used to change the gut-brain axis. These medications are intended to regulate the levels of metabolites that influence mood, cognitive function, and brain health.	(Alonso *et al*., 2014)
Neurotransmitter modulators	Medications designed to modulate the production and regulation of specific neurotransmitters. These medications may influence neurotransmitter balance and improve mental well-being.	(Mittal *et al*., 2017)
Immunomodulators	Medications that target the immune system and lower gut inflammation may have an indirect effect on the gut-brain axis. These drugs can improve brain health and potentially lower the risk of neuroinflammatory diseases by reducing chronic inflammation.	(Hemarajata and Versalovic, 2013)
Bacterial signaling disruptors	Immunomodulators and anti-inflammatory medications may have an indirect influence on the gut-brain axis. By lowering chronic inflammation, these medications can improve brain health and potentially lessen the risk of neuroinflammatory disorders.	(Hampl and Stárka, 2020)

Conclusion

The gut-brain axis is a fascinating area of research that has revealed the substantial influence of the gut microbiota on the neurological health. A balanced and diverse gut microbiota is crucial for maintaining the cognitive function, regulating the mood, and potentially preventing the neurodegenerative diseases. As our understanding of this complex relationship deepens, it opens up exciting possibilities for novel therapeutic interventions that may improve the lives of those individuals with neurological disorders. However, more research is needed to fully comprehend the intricacies of the gut-brain axis and its therapeutic potential.

Acknowledgment

None to declare.

Conflict of interests

There are no conflicts of interest to declare.

Funding

This study did not receive any fund.

Ethical approval

None-applicable.

Author’s Contributions

Conceptualization: R.G., A.D.; Investigation: G.S; Supervision: R.G., M.A.; Writing, reviewing, and editing: R.G., A.D., M.A and G.S.; Roles/Writing - original draft: R.G.

7. References

Ağagündüz, D.; Icer, M.A.; Yesildemir, O.; Koçak, T.; Kocyigit, E. and Capasso, R. (2023). The roles of dietary lipids and lipidomics in gut-brain axis in type 2 diabetes mellitus. Journal of Translational Medicine. 21(1): 240-248. https://doi.org/10.1186/s12967-023-04088-5

Agirman, G.; Yu, K.B. and Hsiao, E.Y. (2021). Signalling inflammation across the gut-brain axis. Science. 374(2): 1087-1092. https://doi.org/10.1126/science.abi6087

Agustí, A.; García-Pardo, M.P.; López-Almela, I.; Campillo, I.; Maes, M.; Romaní-Pérez, M. et al. (2018). Interplay between the gut-brain axis, obesity and cognitive function. Frontiers in Neuroscience. 12: 155. https://doi.org/10.3389/fnins.2018.00155

Alonso, C.; Vicario, M.; Pigrau, M.; Lobo, B. and Santos, J. (2014). Intestinal Barrier Function and the Brain-Gut Axis. In: Lyte, M. and Cryan, J. (Editors) Microbial Endocrinology: The Microbiota-Gut-Brain Axis in Health and Disease. Advances in Experimental Medicine and Biology. 817. Springer, New York, NY. https://doi.org/10.1007/978-1-4939-0897-4_4

Barber, T.M.; Valsamakis, G.; Mastorakos, G.; Hanson, P.; Kyrou, I.; Randeva, H.S. et al. (2021). Dietary influences on the microbiota–gut–brain axis. International Journal of Molecular Sciences. 22(7): 3502-3509. https://doi.org/10.3390/ijms22073502

Bear, T.; Dalziel, J.; Coad, J.; Roy, N.; Butts, C. and Gopal, P. (2021). The microbiome-gut-brain axis and resilience to developing anxiety or depression under stress. Microorganisms. 9(4): 723-729. https://doi.org/10.3390/microorganisms9040723

Benakis, C.; Martin-Gallausiaux, C.; Trezzi, J.P.; Melton, P., Liesz, A. and Wilmes, P. (2020). The microbiome-gut-brain axis in acute and chronic brain diseases. Current Opinion in Neurobiology. 61(1): 1-9. https://doi.org/10.1016/j.conb.2019.11.009

Berding, K.; Carbia, C. and Cryan, J.F. (2021a). Going with the grain: Fiber, cognition, and the microbiota-gut-brain-axis. Experimental Biology and Medicine. 246(7): 796-811. https://doi.org/10.1177/1535370221995785

Berding, K.; Vlckova, K.; Marx, W.; Schellekens, H.; Stanton, C.; Clarke, G. et al. (2021b). Diet and the microbiota–gut–brain axis: sowing the seeds of good mental health. Advances in Nutrition. 12(4): 1239-1285. https://doi.org/10.1093/advances/nmaa181

Bistoletti, M.; Bosi, A.; Banfi, D.; Giaroni, C. and Baj, A. (2020). The microbiota-gut-brain axis: Focus on the fundamental communication pathways. Progress in Molecular Biology and Translational Science. 176: 43-110. https://doi.org/10.1016/bs.pmbts.2020.08.012

Brewer-Smyth, K. (2022). Brain Food: The Impact of Diet, Nutrition, and Nutraceuticals on the Brain and the Microbiota-Gut-Brain Axis. In: Adverse Childhood Experiences. Springer, Cham. https://doi.org/10.1007/978-3-031-08801-8_12

Cammarota, G.; Ianiro, G.; Bibbò, S. and Gasbarrini, A. (2014). Gut microbiota modulation: probiotics, antibiotics or fecal microbiota transplantation?. Internal and Emergency Medicine. 9: 365-373. https://doi.org/10.1007/s11739-014-1069-4

Chen, Y.; Xu, J. and Chen, Y. (2021). Regulation of neurotransmitters by the gut microbiota and effects on cognition in neurological disorders. Nutrients. 13(6): 2099. https://doi.org/10.3390/nu13062099

Chu, C.Q.; Yu, L.L.; Chen, W.; Tian, F.W. and Zhai, Q.X. (2021). Dietary patterns affect Parkinson's disease via the microbiota-gut-brain axis. Trends in Food Science & Technology. 116: 90-101. https://doi.org/10.1016/j.tifs.2021.07.004

Clapp, M.; Aurora, N.; Herrera, L.; Bhatia, M.; Wilen, E. and Wakefield, S. (2017). Gut microbiota's effect on mental health: The gut-brain axis. Clinics and Practice. 7(4): 987. https://doi.org/10.4081/cp.2017.987

Cryan, J.F.; O'Riordan, K.J.; Cowan, C.S.; Sandhu, K.V.; Bastiaanssen, T.F.; Boehme, M. et al. (2019). The microbiota-gut-brain axis. Physiological Reviews. 99: 1877-2013. https://doi.org/10.1152/physrev.00018.2018

Dahiya, D. and Nigam, P.S. (2022). Probiotics, prebiotics, synbiotics, and fermented foods as potential biotics in nutrition improving health *via* microbiome-gut-brain axis. Fermentation. 8(7): 303. https://doi.org/10.3390/fermentation8070303

Dalile, B.; Van Oudenhove, L.; Vervliet, B. and Verbeke, K. (2019). The role of short-chain fatty acids in microbiota–gut–brain communication. Nature Reviews Gastroenterology & Hepatology. 16(8): 461-478. https://doi.org/10.1038/s41575-019-0157-3

De la Fuente, M. (2021). The role of the microbiota-gut-brain axis in the health and illness condition: a focus on Alzheimer's disease. Journal of Alzheimer's Disease. 81(4): 1345-1360. https://doi.org/10.3233/JAD-201587

Defaye, M.; Gervason, S.; Altier, C.; Berthon, J.Y.; Ardid, D.; Filaire, E. et al. (2020). Microbiota: a novel regulator of pain. Journal of Neural Transmission. 127: 445-465. https://doi.org/10.1007/s00702-019-02083-z

Dicks, L.M. (2022). Gut bacteria and neurotransmitters. Microorganisms. 10(9): 1838. https://doi.org/10.3390/microorganisms10091838

Ding, J.H.; Jin, Z.; Yang, X.X.; Lou, J.; Shan, W.X.; Hu, Y.X. et al. (2020). Role of gut microbiota via the gut-liver-brain axis in digestive diseases. World Journal of Gastroenterology. 26(40): 6141. https://doi.org/10.3748%2Fwjg.v26.i40.6141

Donoso, F.; Cryan, J.F.; Olavarría-Ramírez, L.; Nolan, Y.M. and Clarke, G. (2023). Inflammation, Lifestyle Factors, and the Microbiome-Gut-Brain Axis: Relevance to Depression and Antidepressant Action. Clinical Pharmacology & Therapeutics. 113(2): 246-259. https://doi.org/10.1002/cpt.2581

Doroszkiewicz, J.; Groblewska, M. and Mroczko, B. (2021). The role of gut microbiota and gut–brain interplay in selected diseases of the central nervous system. International Journal of Molecular Sciences. 22(18): 10028. https://doi.org/10.3390/ijms221810028

Dumitrescu, L.; Popescu-Olaru, I.; Cozma, L.; Tulbă, D.; Hinescu, M.E.; Ceafalan, L.C. et al. (2018). Oxidative stress and the microbiota-gut-brain axis. Oxidative Medicine and Cellular Longevity. 2018: 2406594. https://doi.org/10.1155/2018/2406594

El Aidy, S.; Dinan, T.G. and Cryan, J.F. (2015). Gut microbiota: the conductor in the orchestra of immune–neuroendocrine communication. Clinical Therapeutics. 37(5): 954-967. https://doi.org/10.1016/j.clinthera.2015.03.002

Evrensel, A. and Tarhan, K.N. (2021). Emerging role of Gut-microbiota-brain axis in depression and therapeutic implication. Progress in Neuro-Psychopharmacology and Biological Psychiatry. 106: 110-138. https://doi.org/10.1016/j.pnpbp.2020.110138

Foster, J.A.; Rinaman, L. and Cryan, J.F. (2017). Stress & the gut-brain axis: regulation by the microbiome. Neurobiology of Stress. 7: 124-136. https://doi.org/10.1016/j.ynstr.2017.03.001

Ghaisas, S.; Maher, J. and Kanthasamy, A. (2016). Gut microbiome in health and disease: Linking the microbiome–gut–brain axis and environmental factors in the pathogenesis of systemic and neurodegenerative diseases. Pharmacology & Therapeutics. 158: 52-62. https://doi.org/10.1016/j.pharmthera.2015.11.012

Ghanei, N.; Saghazadeh, A. and Rezaei, N. (2019). Gut Microbiome and Immunity. Nutrition and Immunity. 167-181. https://doi.org/10.1007/978-3-030-16073-9_10

Ghosh, D. (2021). Role of food or food component in brain health. Nutraceuticals in Brain Health and Beyond. pp. 3-13. https://doi.org/10.1016/B978-0-12-820593-8.00002-1

Gwak, M.G. and Chang, S.Y. (2021). Gut-brain connection: microbiome, gut barrier, and environmental sensors. Immune Network. 21(3): e20. https://doi.org/10.4110%2Fin.2021.21.e20

Hampl, R. and Stárka, L. (2020). Endocrine disruptors and gut microbiome interactions. Physiological Research, 69(Suppl 2). S211–S223. https://doi.org/10.33549%2Fphysiolres.934513

Han, Y.; Wang, B.; Gao, H.; He, C.; Hua, R.; Liang, C. et al. (2022). Vagus nerve and underlying impact on the gut microbiota-brain Axis in behavior and neurodegenerative diseases. Journal of Inflammation Research. 6213-6230. https://doi.org/10.2147/JIR.S384949

Hemarajata, P. and Versalovic, J. (2013). Effects of probiotics on gut microbiota: mechanisms of intestinal immunomodulation and neuromodulation. Therapeutic Advances in Gastroenterology. 6(1): 39-51. https://doi.org/10.1177/1756283X12459294

Hillestad, E.M.R.; Van der Meeren, A.; Nagaraja, B.H.; Bjørsvik, B.R.; Haleem, N.; Benitez-Paez, A. et al. (2022). Gut bless you: The microbiota-gut-brain axis in irritable bowel syndrome. World Journal of Gastroenterology. 28(4): 412. https://doi.org/10.3748%2Fwjg.v28.i4.412

Hu, B.; Das, P.; Lv, X.; Shi, M.; Aa, J.; Wang, K. et al. (2022). Effects of 'healthy'fecal microbiota transplantation against the deterioration of depression in fawn-hooded rats. Msystems. 7(3): e00218-22. https://doi.org/10.1128/msystems.00218-22

Hyland, N. and Stanton, C. (2023). The gut-brain axis: Dietary, probiotic, and prebiotic interventions on the microbiota. 2nd Edition. Elsevier.

Joshi, D.; Roy, S. and Banerjee, S. (2018). Prebiotics: A functional food in health and disease. In: Natural Products and Drug Discovery. pp. 507-523. https://doi.org/10.1016/B978-0-08-102081-4.00019-8

Kandpal, M.; Indari, O.; Baral, B.; Jakhmola, S.; Tiwari, D.; Bhandari, V. et al. (2022). Dysbiosis of Gut Microbiota from the Perspective of the Gut–Brain Axis: Role in the Provocation of Neurological Disorders. Metabolites. 12(11): 1064. https://doi.org/10.3390/metabo12111064

Kaur, H.; Bose, C. and Mande, S.S. (2019). Tryptophan metabolism by gut microbiome and gut-brain-axis: An *in silico* analysis. Frontiers in Neuroscience. 13: 493-713. https://doi.org/10.3389/fnins.2019.01365

Kavvadia, M.; Santis, G.L.D.; Alwardat, N.A.A.; Bigioni, G.; Zeppieri, C.; Cascapera, S. and Lorenzo, A.D. (2017). Psychobiotics as integrative therapy for neuropsychiatric disorders with special emphasis on the microbiota-gut-brain axis. Biomed Prevention 2(8): 81-88. https://doi.org/10.19252/00000006F

Keightley, P.C.; Koloski, N.A. and Talley, N.J. (2015). Pathways in gut-brain communication: evidence for distinct gut-to-brain and brain-to-gut syndromes. Australian & New Zealand Journal of Psychiatry. 49(3): 207-214. https://doi.org/10.1177/0004867415569801

Kesika, P.; Suganthy, N.; Sivamaruthi, B.S. and Chaiyasut, C. (2021). Role of gut-brain axis, gut microbial composition, and probiotic intervention in Alzheimer's disease. Life Sciences. 264: 118-627. https://doi.org/10.1016/j.lfs.2020.118627

Kuwahara, A.; Matsuda, K.; Kuwahara, Y.; Asano, S.; Inui, T. and Marunaka, Y. (2020). Microbiota-gut-brain axis: Enteroendocrine cells and the enteric nervous system form an interface between the microbiota and the central nervous system. Biomedical Research. 41(5): 199-216. https://doi.org/10.2220/biomedres.41.199

LaGreca, M.; Hutchinson, D.R. and Skehan, L. (2021). The microbiome and neurotransmitter activity. The Journal of Science and Medicine. 3(2): 1-16. https://www.josam.org/josam/article/view/90?download=pdf

Lasrado, L.D. and Rai, A.K. (2022). Use of Prebiotics for addressing gut dysbiosis and achieving healthy gut–brain axis. In: Probiotic Research in Therapeutics. Volume 5: Metabolic Diseases and Gut Bacteria. 5: 207-239. Singapore: Springer Nature Singapore. https://link.springer.com/chapter/10.1007/978-981-16-8444-9_11

Leprun, P.M. and Clarke, G. (2019). The gut microbiome and pharmacology: a prescription for therapeutic targeting of the gut–brain axis. Current Opinion in Pharmacology. 49: 17-23. https://doi.org/10.1016/j.coph.2019.04.007

Liang, S.; Wu, X. and Jin, F. (2018). Gut-brain psychology: rethinking psychology from the microbiota–gut–brain axis. Frontiers in Integrative Neuroscience. 33: 391-492. https://doi.org/10.3389/fnint.2018.00033

Limas-Solano, L.M.; Vargas-Niño, C.E.; Valbuena-Rodríguez, D.C. and Ramírez-López, L.X. (2020). Fecal Microbial Transplantation: A Review. Revista Colombiana de Gastroenterología. 35(3): 329-337. https://doi.org/10.22516/25007440.486

Liu, T.; Feenstra, K.A.; Heringa, J. and Huang, Z. (2020). Influence of gut microbiota on mental health via neurotransmitters: A review. Journal of Artificial Intelligence for Medical Sciences. 1(1-2): 1-14. https://doi.org/10.2991/jaims.d.200420.001

Louwies, T.; Johnson, A.C.; Orock, A.; Yuan, T. and Greenwood-Van Meerveld, B. (2020). The microbiota-gut-brain axis: An emerging role for the epigenome. Experimental Biology and Medicine. 245(2): 138-145. https://doi.org/10.1177/1535370219891690

Ma, Q.; Xing, C.; Long, W.; Wang, H.Y.; Liu, Q. and Wang, R.F. (2019). Impact of microbiota on central nervous system and neurological diseases: the gut-brain axis. Journal of Neuroinflammation. 16(1): 1-14. https://doi.org/10.1186/s12974-019-1434-3

Maiuolo, J.; Gliozzi, M.; Musolino, V.; Carresi, C.; Scarano, F.; Nucera, S. et al. (2021). The contribution of gut microbiota–brain axis in the development of brain disorders. Frontiers in

Neuroscience. 15: 616-883. https://doi.org/10.3389/fnins.2021.616883

Majumdar, A.; Siva Venkatesh, I.P. and Basu, A. (2023). Short-Chain Fatty Acids in the Microbiota–Gut–Brain Axis: Role in Neurodegenerative Disorders and Viral Infections. ACS Chemical Neuroscience. 14(6): 1045-1062. https://doi.org/10.1021/acschemneuro.2c00803

Manderino, L.; Carroll, I.; Azcarate-Peril, M.A.; Rochette, A.; Heinberg, L.; Peat, C. et al. (2017). Preliminary evidence for an association between the composition of the gut microbiome and cognitive function in neurologically healthy older adults. Journal of the International Neuropsychological Society. 23(8): 700-705. https://doi.org/10.1017/S1355617717000492

Margolis, K.G.; Cryan, J.F. and Mayer, E.A. (2021). The microbiota-gut-brain axis: from motility to mood. Gastroenterology. 160(5): 1486-1501. https://doi.org/10.1053/j.gastro.2020.10.066

Mendes, K.L.; de Farias Lelis, D.; Athayde Souza, L.A.; Brito, R.V.; Andrade, M.C.; Nobre, S.A.M. et al. (2021). *Lactococcus lactis* and resveratrol decrease body weight and increase benefic gastrointestinal microbiota in mice. Protein and Peptide Letters. 28(7): 761-768. https://doi.org/10.2174/0929866527999201209214850

Mitrea, L.; Nemeş, S.A.; Szabo, K.; Teleky, B.E. and Vodnar, D.C. (2022). Guts imbalance imbalances the brain: a review of gut microbiota association with neurological and psychiatric disorders. Frontiers in Medicine. 31(9): 706.| https://doi.org/10.3389/fmed.2022.813204

Mittal, R.; Debs, L.H.; Patel, A.P.; Nguyen, D.; Patel, K.; O'Connor, G. et al. (2017). Neurotransmitters: The critical modulators regulating gut–brain axis. Journal of Cellular Physiology. 232(9): 2359-2372. https://doi.org/10.1002/jcp.25518

Moţăţăianu, A.; Şerban, G. and Andone, S. (2023). The role of short-chain fatty acids in microbiota–gut–brain cross-talk with a focus on amyotrophic lateral sclerosis: a systematic review. International Journal of Molecular Sciences. 24(20): 150-94.https://doi.org/10.3390/ijms242015094

Mukhtar, K.; Nawaz, H. and Abid, S. (2019). Functional gastrointestinal disorders and gut-brain axis: What does the future hold?. World Journal of Gastroenterology. 25(5): 552. https://doi.org/10.3748%2Fwjg.v25.i5.552

Naveed, M.; Zhou, Q.G.; Xu, C.; Taleb, A.; Meng, F.; Ahmed, B. et al. (2021). Gut-brain axis: A matter of concern in neuropsychiatric disorders. Progress in Neuro-Psychopharmacology and Biological Psychiatry. 104: 110051. https://doi.org/10.1016/j.pnpbp.2020.110051

Neri, I.; Boschetti, E.; Follo, M.Y.; De Giorgio, R.; Cocco, L.I.; Manzoli, L. et al. (2023). Microbiota-gut-brain axis in neurological disorders: from leaky barriers microanatomical changes to biochemical processes. Mini Reviews in Medicinal Chemistry. 23(3): 307-319. https://doi.org/10.2174/1389557522666220622111501

Oriach, C.S.; Robertson, R.C.; Stanton, C.; Cryan, J.F. and Dinan, T.G. (2016). Food for thought: The role of nutrition in the microbiota-gut–brain axis. Clinical Nutrition Experimental. 6: 25-38. https://doi.org/10.1016/j.yclnex.2016.01.003

O'Riordan, K.J.; Collins, M.K.; Moloney, G.M.; Knox, E.G.; Aburto, M.R.; Fülling, C. et al. (2022). Short chain fatty acids: Microbial metabolites for gut-brain axis signalling. Molecular and Cellular Endocrinology. 546: 111-572. https://doi.org/10.1016/j.mce.2022.111572

Oroojzadeh, P.; Bostanabad, S.Y. and Lotfi, H. (2022). Psychobiotics: the influence of gut microbiota on the gut-brain axis in neurological disorders. Journal of Molecular Neuroscience. 72(9): 1952-1964. https://doi.org/10.1007/s12031-022-02053-3

Petra, A.I.; Panagiotidou, S.; Hatziagelaki, E.; Stewart, J.M.; Conti, P. and Theoharides, T.C. (2015). Gut-microbiota-brain axis and its effect on neuropsychiatric disorders with suspected immune dysregulation. Clinical Therapeutics. 37(5): 984-995. https://doi.org/10.1016/j.clinthera.2015.04.002

Pizarroso, N.A.; Fuciños, P.; Gonçalves, C.; Pastrana, L. and Amado, I.R. (2021).A review on the role of food-derived bioactive molecules and the microbiota–gut–brain axis in satiety regulation. Nutrients. 13(2): 63. https://doi.org/10.3390/nu13020632

Qian, X.H.; Xie, R.Y.; Liu, X.L. and Tang, H.D. (2022). Mechanisms of short-chain fatty acids derived from gut microbiota in Alzheimer's disease. Aging and Disease. 13(4): 1252. https://doi.org/10.14336%2FAD.2021.1215

Quigley, E.M. (2005). Irritable bowel syndrome and inflammatory bowel disease: interrelated diseases?. Chinese Journal of Digestive Diseases. 6(3): 122-132. https://doi.org/10.1111/j.1443-9573.2005.00202.x

Raimondi, I.; Izzo, L.; Tunesi, M.; Comar, M.; Albani, D. and Giordano, C. (2020). Organ-on-a-chip *in vitro* models of the brain and the blood-brain barrier and their value to study the microbiota-gut-brain axis in neurodegeneration. Frontiers in Bioengineering and Biotechnology. 7: 435. https://doi.org/10.3389/fbioe.2019.00435

Roe, K. (2022). An alternative explanation for Alzheimer's disease and Parkinson's disease initiation from specific antibiotics, gut microbiota dysbiosis and neurotoxins. Neurochemical Research. 47(3): 517-530. https://doi.org/10.1007/s11064-021-03467-y

Sajdel-Sulkowska, E.M. and Zabielski, R. (2013). Gut microbiome and brain-gut axis in autism-aberrant development of gut-brain communication and reward circuitry. In: Recent Advances in Autism Spectrum Disorders. Volume I. https://doi.org/10.5772/55425

Sandhu, K.V.; Sherwin, E.; Schellekens, H.; Stanton, C.; Dinan, T.G. and Cryan, J.F. (2017). Feeding the microbiota-gut-brain axis: diet, microbiome, and neuropsychiatry. Translational Research. 179: 223-244. https://doi.org/10.1016/j.trsl.2016.10.002

Serra, D.; Almeida, L.M. and Dinis, T.C. (2019). The impact of chronic intestinal inflammation on brain disorders: The microbiota-gut-brain axis. Molecular Neurobiology. 56: 6941-6951. https://doi.org/10.1007/s12035-019-1572-8

Silva, Y.P.; Bernardi, A. and Frozza, R.L. (2020). The role of short-chain fatty acids from gut microbiota in gut-brain communication. Frontiers in Endocrinology. 11: 25. https://doi.org/10.3389/fendo.2020.00025

Skonieczna-Żydecka, K.; Marlicz, W.; Misera, A.; Koulaouzidis, A. and Łoniewski, I. (2018). Microbiome—the missing link in the gut-brain axis: focus on its role in gastrointestinal and mental health. Journal of Clinical Medicine. 7(12): 521. https://doi.org/10.3390/jcm7120521

Socała, K.; Doboszewska, U.; Szopa, A.; Serefko, A.; Włodarczyk, M.; Zielińska, A. et al. (2021). The role of microbiota-gut-brain axis in neuropsychiatric and neurological disorders. Pharmacological Research. 172: 105-840. https://doi.org/10.1016/j.phrs.2021.105840

Suganya, K. and Koo, B.S. (2020). Gut–brain axis: role of gut microbiota on neurological disorders and how probiotics/prebiotics beneficially modulate microbial and immune pathways to improve brain functions. International Journal of Molecular Sciences. 21(20): 75-51. https://doi.org/10.3390/ijms21207551

Sun, P.; Su, L.; Zhu, H.; Li, X.; Guo, Y.; Du, X. et al. (2021). Gut microbiota regulation and their implication in the development of neurodegenerative disease. Microorganisms. 9(11): 22-81. https://doi.org/10.3390/microorganisms9112281

Sun, L.J.; Li, J.N. and Nie, Y.Z. (2020). Gut hormones in microbiota-gut-brain cross-talk. Chinese Medical Journal. 133(07): 826-833. https://doi.org/10.1097/CM9.0000000000000706

Thangaleela, S.; Sivamaruthi, B.S.; Kesika, P. and Chaiyasut, C. (2022). Role of Probiotics and Diet in the Management of Neurological Diseases and Mood States: A Review. Microorganisms. 10(11): 22-68. https://doi.org/10.3390/microorganisms10112268

Torres-Fuentes, C.; Schellekens, H.; Dinan, T.G. and Cryan, J.F. (2017). The microbiota–gut–brain axis in obesity. The Lancet Gastroenterology & Hepatology. 2(10):747-756. https://doi.org/10.1016/S2468-1253(17)30147-4

Van de Wouw, M.; Schellekens, H.; Dinan, T.G. and Cryan, J.F. (2017). Microbiota-gut-brain axis: modulator of host metabolism and appetite. The Journal of Nutrition. 147(5): 727-745. https://doi.org/10.3945/jn.116.240481

Wang, H.X. and Wang, Y.P. (2016). Gut microbiota-brain axis. Chinese Medical Journal. 129(19): 2373-2380. https://doi.org/10.4103/0366‑6999

Westfall, S.; Lomis, N.; Kahouli, I.; Dia, S.Y.; Singh, S.P. and Prakash, S. (2017). Microbiome, probiotics and neurodegenerative diseases: deciphering the gut brain axis. Cellular and Molecular Life Sciences. 74: 3769-3787. https://doi.org/10.1007/s00018-017-2550-9

Wiley, N.C.; Dinan, T.G.; Ross, R.P.; Stanton, C.; Clarke, G. and Cryan, J.F. (2017). The microbiota-gut-brain axis as a key regulator of neural function and the stress response: Implications for human and animal health. Journal of Animal Science. 95(7): 3225-3246. https://doi.org/10.2527/jas.2016.1256

Woo, V. and Alenghat, T. (2022). Epigenetic regulation by gut microbiota. Gut Microbes. 14(1): 2022407. https://doi.org/10.1080/19490976.2021.2022407

Yuan, C.; He, Y.; Xie, K.; Feng, L.; Gao, S. and Cai, L. (2023). Review of microbiota gut brain axis and innate immunity in inflammatory and infective diseases. Frontiers in Cellular and Infection Microbiology. 13: 1282431. https://doi.org/10.3389%2Ffcimb.2023.1282431

Zhu, R.; Liu, L.; Zhang, G.; Dong, J.; Ren, Z. and Li, Z. (2023). The pathogenesis of gut microbiota in hepatic encephalopathy by the gut-liver-brain axis. Bioscience Reports. 43(6): 2022-2524. .https://doi.org/10.1042/BSR20222524

Zhu, X.; Han, Y.; Du, J.; Liu, R.; Jin, K. and Yi, W. (2017). Microbiota-gut-brain axis and the central nervous system. Oncotarget. 8(32): 53829. https://doi.org/10.18632%2Foncotarget.17754