

# Navigating the effects of Gut Microbiome on the Human Mind: A Review

Yaayin

Student, SGN Senior Secondary Public school, Delhi

## Abstract

Recent developments in the field of bacteriology and gastroenterology have highlighted the possible significance of the gut-microbiome of the quality of life through the changes caused in the neurotransmitter profile. Studies show that various neurotransmitters are impacted due to the microbes present in our guts, this is due to the bi-directional communication between the gut and the brain, collectively known as the gut-brain axis. Studies in bacterial populations point to the conclusion that neurotransmitters are greatly influenced by their actions, which causes fluctuations in the level of neurotransmitters resulting in varied mood states/mental conditions. The available literature has illuminated the ability of gut bacteria to alter the synthesis and metabolism of neurotransmitters, such as serotonin, dopamine, and acetylcholine. These alterations in neurotransmitter levels give rise to a spectrum of mental states and conditions that significantly influence daily life. This research highlights the potential for altering the microbiome in order to potentially improve mental health cognitive function and overall well being. The practice of modulating the populations of gut microbes could prove to be a significant step in improving the quality of everyday life due to its great impact on being able to regulate major neurotransmitters present in the body, which allows one to navigate through daily life without abnormal fluctuations of neurotransmitters and avoid serious mental conditions.

**Keywords:** Gut Microbiome, Gut brain axis, Enteric Nervous system, neurotransmitters.

## Introduction

The gut-brain axis is a mode of communication between the gut and the brain; it has emerged as an important factor influencing various aspects of mental health. Bacteria in our gut communicate with our brain through basic body processes and influencing the gut microbiome could positively affect the state of our mental health. Various interactions through the gut-brain axis impact the creation of neurotransmitters, which affect mood and many other functions, alteration or enhancement of the quality of the microbiome could prove to be paramount in terms of enhancing mental wellbeing and the general quality of life among the masses through behavioural and dietetic changes. The microbiome is greatly correlated with mental health disorders and stress. Research suggests that the gut microbiome composition has been linked to conditions such as anxiety, depression, and even neural disorders like autism spectrum disorder, its implications also include but aren't limited to impacts on cognitive abilities, memory and concentration. [1]

The disturbance in the gut flora expresses itself through mental health disorders which include but aren't limited to anxiety and depression. To alter the gut microbiome, dietary changes could be made, which

include incorporating more fibre-rich foods, fermented products etc. An active lifestyle with emphasis on promoting low stress, and avoiding unnecessary antibiotic use can positively affect gut bacteria, resulting in a balanced and diverse gut microbiome.

Our body houses approximately 37 trillion cells, surprisingly on a microcosm scale things take an unexpected turn, research suggests that the gut of an average human being is home to approximately ~39 trillion microbes. Those microbes continuously communicate with the brain through nerves, while their weight is the same as that of the brain i.e 2kg.

The vast diversity and scale of the microorganisms residing in the gastrointestinal tract is collectively referred to as the gut-flora or the gut microbiota. It comprises a wide range of bacteria, viruses, fungi, archaea, and other microbes. Specific bacteria can be declared as beneficial companions, meaning they live in a symbiotic relationship with the human host. Whilst, others have been classified as potential pathogens and a disturbance in the proportions of these bacteria could increase the susceptibility of the individual to various diseases and ailments. [1,2]

**Literature Review**

**Gut and Brain connection**

The gut-brain axis is a communication pathway between the gut and the brain, it operates bidirectionally. In other terms, the gut-brain axis is a communication pathway between the gut and brain which has several components such as the ENS and the CNS mainly, amongst many others, they all work together, passing messages back and forth, influencing your mental state and the state of your gut. A major factor involving the gut brain axis is the Gut Microbiome.[3]

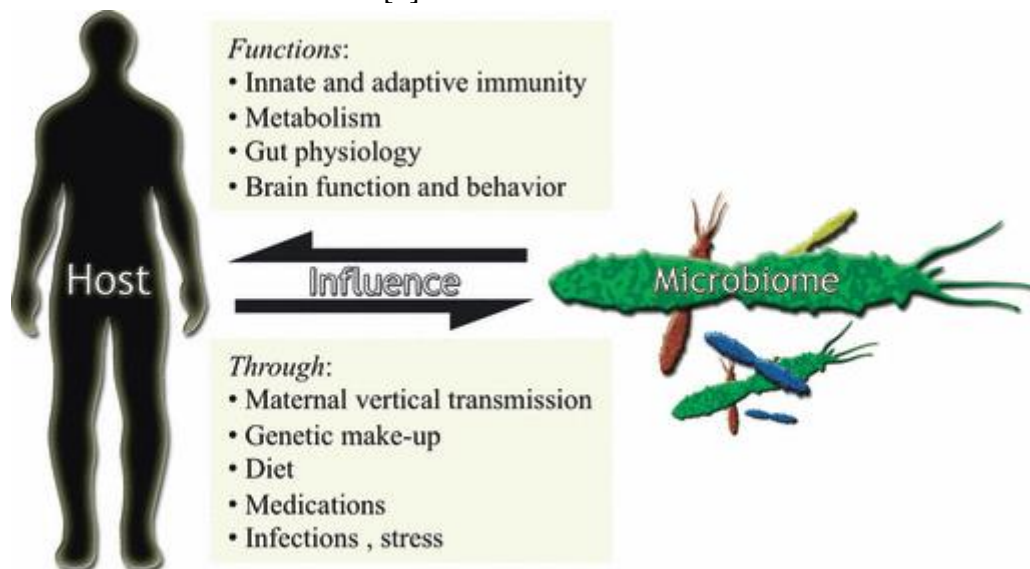


Figure 1. The intestinal microbiome: a complex and dynamic ecosystem that establishes bi-directional interactions with the host<sup>3</sup>

The two-way nature of the gut and the brain means that the gut influences the brain and vice versa. Some of these factors which enable the communication between the two include several nerves, primarily the vagus nerve which conducts signals from the ENS to the CNS.

Neurotransmitters and hormones play a major role, the gut produces several neuro transmitters, due to the activity of the microbiota, which express themselves in the brain by causing alteration of mood and emotions, these reach the brain either through neural pathways or via the bloodstream.[3]

**Dopamine**

Dopamine is a neurotransmitter which plays a crucial role in major bodily processes including, but not limited to: Motivation, motor control, cognition and learning, modulating the release and receptivity of other hormones etc. It binds to the dopamine receptors present in the Central Nervous System(the brain and the spinal cord, the Peripheral Nervous System including the ENS and Cardiovascular Nervous System.

Many microbes were found to be involved in the synthesis of this hormone, some of them are responsible for dopamine-synthesis in the gut, these include *Proteus vulgaris* and *E. coli*. These can be found in the human gut and are associated with production of dopamine.[4]

**Acetylcholine**

Acetylcholine is one of the most predominant neurotransmitters in the body. It is responsible for mediating functions such as learning, memory, attention, and problem-solving. Proper Acetylcholine function is essential for higher brain functions and mental clarity.

Studies point to the conclusion that while Acetylcholine is not directly produced by the gut bacteria, the bacteria play a crucial role in influencing its levels, through production of its precursors in the gut. Majorly bacteria such as *Lactobacillus*, *Bifidobacterium*, and certain other bacteria in the gut are known to produce precursors of acetylcholine.

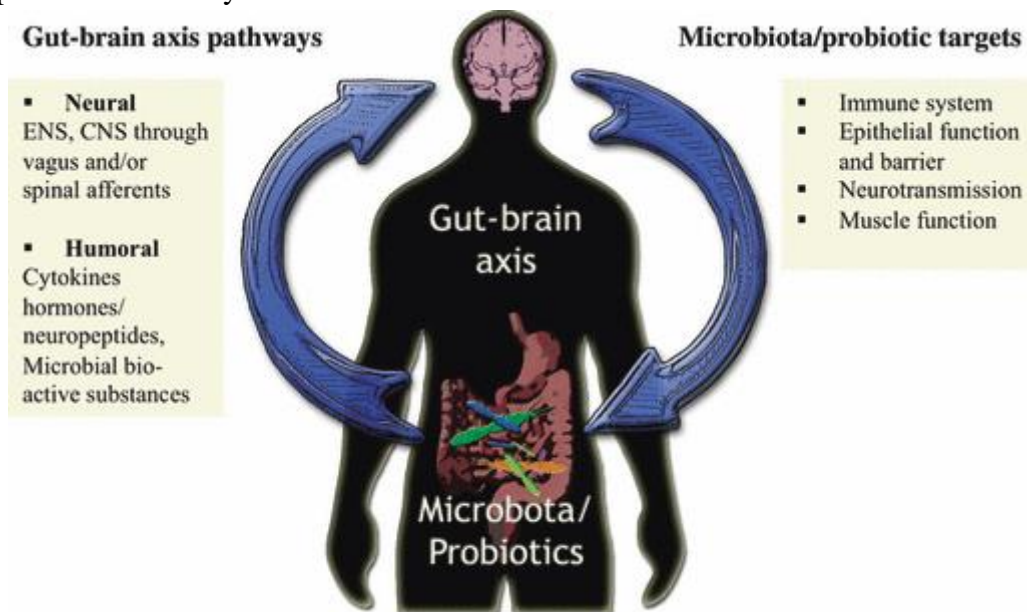


Figure 2. The gut-brain axis. Pathways of communication and probiotic targets<sup>3</sup>

### Serotonin

Serotonin is a neurotransmitter which influences various physical and mental aspects. It is responsible for regulating moods, emotions, feelings of “well-being” and is often titled the “happy hormone”.

More than 90% of the body’s 5-HT is synthesised in the gut. Certain microbes are directly involved in the production of serotonin. Indigenous Spore-Forming Microbes in the gut play a major role in synthesising serotonin, the exact species weren’t derived through the researches, but their role was highlighted significantly.[4]

### GABA

Gamma-aminobutyric acid (GABA) is a crucial neurotransmitter involved in various bodily processes such as monitoring muscular contractions, altering the body's response to stress, promoting anxiety and stress reduction amongst many others.

Research suggests that the human gut microbiome contains bacteria capable of synthesising GABA. It was discovered that GABA is produced by *Bacteroides Fragilis*, along with several others such as *Parabacteroids*, *Eubacterium* and *Bifidobacterium*.[4]

### Cortisol

Although cortisol is not directly produced by the gut microbiota, it can significantly influence its level in the body through production of precursors such as 21-deoxycortisol. Current literature points to the presence of *C. scindens* an anaerobe that was shown to metabolise cortisol and convert it to 21-deoxycortisol, as a result, *Clostridium* *scindens* contributes to the metabolism and reduction of cortisol within the gut Microbiome. Also, *Lactobacillus helveticus* and *Bifidobacterium longum* were found to reduce cortisol levels and anxiety like behavior in rats and humans.[5]

### Noradrenaline

It is a hormone responsible for numerous functions in the body, one of the primary actions modulated by noradrenaline is the body's stress response commonly known as “fight or flight”. Besides this, it plays a significant role in alertness and attention, along with memory and focus. Some research has suggested that gut bacteria, including *E. coli* and *Proteus vulgaris*, may be involved in the production of noradrenaline in the gut. However, more extensive research is needed to identify the precise bacteria and mechanisms involved in noradrenaline production in the human gut.[4]

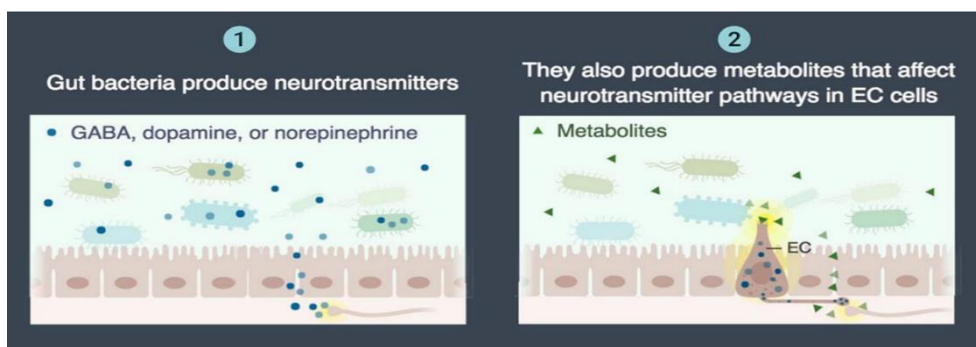


Figure 3. Neurotransmitters interact with enteric or PNS<sup>4</sup>

A combined effect of all or some of the neurotransmitters mentioned above, results in the expression of Various mood states. Mood states to be considered are:

### **Anxiety**

Anxiety is a complex condition characterised by excessive fear and worry, irritability, struggling to focus on a task due to interrupting distressing thoughts, shortness of breath, elevated heart rate etc. It is influenced by various neurotransmitters and hormones, whose low or high levels in the body contribute to the condition. Abnormally elevated levels of epinephrine and cortisol produce an anxious state of the mind. Whereas, normal - elevated levels of hormones including serotonin and GABA. Further research is required on the influence of dopamine on anxiety, current evidence points to the conclusion that low dopamine promotes an anxiety prone mind.[6]

### **Depression**

Depression is a very serious mental health condition characterised by persistent feelings of sadness, hopelessness and a loss of interest in daily activities. It is correlated primarily with the imbalances of the neurotransmitters serotonin and dopamine. Lowered levels of these neurotransmitters over a prolonged period result in the expression of depression.[7]

### **Motivation**

Motivation refers to a state of mind when the person is incredibly driven to carry out a task/action. Motivation is primarily influenced by Dopamine, often regarded as the “Motivation Molecule”. Elevated dopamine levels are linked with an increase in motivation. Release of dopamine reinforces the motivation to repeat actions that lead to positive outcomes.[8]

### **Mental Clarity**

Mental clarity is a complex state of the mind which can be characterised by having a clear, focused mind which allows the individual to swiftly carry out and comprehend tasks which require focus, without a loss in concentration. A clear mind, free from mental fog or distraction can contribute to an increase in concentration, intelligence, memory etc.

This state of clarity is influenced by the activity of several neurotransmitters, whose combined effects alter various mental states leading to a clear fog-free mind. Elevated levels of dopamine enhances mental clarity by promoting determination. Balanced serotonin levels lead to a mental environment suitable for higher mental clarity by influencing general well being of the individual. Excessive levels of norepinephrine and cortisol disrupt the state of mental clarity by promoting anxiety, restlessness, impaires cognitive function and memory.[9]

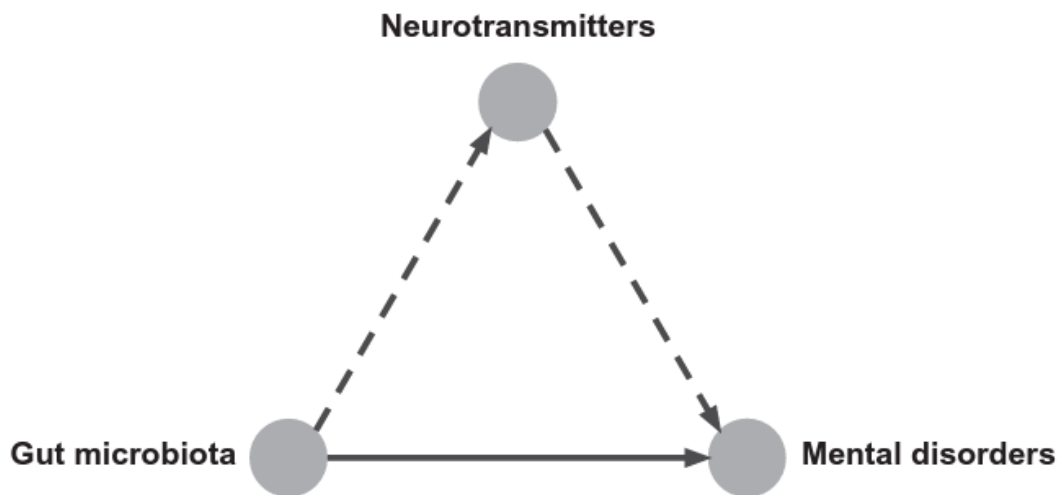


Figure 4. Gut microbiota affects mental health by regulating the level of neurotransmitters<sup>10</sup>

It's important to note that the conditions/states mentioned are influenced by various factors, including genetic predisposition, environmental stressors, and psychological factors. While these neurotransmitters play a role, it is important to take other causative agents into consideration.

### Conclusion

Several bacteria housed in our gut constitute the gut microbiome. Some of them are responsible for the production or moderation of neurotransmitters in the body. The levels of these neurotransmitters are associated with their impacts on core mood states such as mental clarity, motivation, anxiety and conditions such as depression. A disturbed gut microbiome contributes to increased susceptibility to mental conditions, which potentially leads to a vicious cycle of mental and gut-related issues, which significantly affects the general quality of life. The lowered quality of modern day diets negatively affects the gut microbiome, due to its processed nature. An imbalance in the nature and constitution of the microbiota can lead to disruption of the synthesis and metabolism of neurotransmitters which may be detrimental to mental health of an individual. It was determined that production or metabolism of neurotransmitters by specific microbes affects states of the mind and general mental health of an individual significantly.. Therefore, an intervention in improving the quality of gut flora would be fruitful for an individual to check optimal mental health.[10]

### References

1. Elizabeth Thursby, Nathalie Juge (2017); Introduction to the human gut microbiota. *Biochem J* 1 June; 474 (11), <https://doi.org/10.1042/BCJ20160510>
2. Hatton, Ian A et. al. (2023), The human cell count and size distribution, *Proceedings of the National Academy of Sciences*, <https://doi.org/10.1073/pnas.2303077120>
3. Bercik et. al. (2012), Microbes and the gut brain axis, *Neurogastroenterology & Motility*, (24) 405 - 413, <https://doi.org/10.1111/j.1365-2982.2012.01906.x>
4. Strandwitz p (2018), Neurotransmitter modulation by the gut microbiota. *Brain Res*, <https://doi.org/10.1016/j.brainres.2018.03.015>
5. Ly LK et. al. (2021), Gut feelings about bacterial steroid. *Mol Cell Endocrinol*, <https://doi.org/10.1016/j.mce.2021.111174>

6. Łoś K et. al. (2017), Biological Markers in Anxiety Disorders. Journal of Clinical Medicine. 2021; <https://doi.org/10.3390/jcm10081744>
7. Rebecca Strawbridge et. al. (2017), Biomarkers for depression: recent insights, current challenges and future prospects, Neuropsychiatric Disease and Treatment, doi : [10.2147/NDT.S114542](https://doi.org/10.2147/NDT.S114542)
8. Arias-Carrión et. al. (2014), Orquestic regulation of neurotransmitters on reward-seeking behavior. International Arch Medicine, <https://doi.org/10.1186/1755-7682-7-29>
9. Niyonambaza et. al (2019), A Review of Neurotransmitters Sensing Methods for Neuro-Engineering Research. Application of Science, 9, 4719, doi : <https://doi.org/10.3390/app9214719>
10. Liu, Ting, et al.(2020) Influence of gut microbiota on mental health via neurotransmitters: A review. Journal of Artificial Intelligence for Medical Sciences, doi : <https://doi.org/10.2991/jaims.d.200420.001>