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MECHANISMS OF INTERACTION BETWEEN GUT MICROBIOTA AND BRAIN IN MENTAL DISORDERS

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Abstract
In recent years, increasing scientific attention has been directed toward the bidirectional communication between the gastrointestinal tract and the central nervous system, known as the gut–brain axis. Emerging evidence suggests that gut microbiota play a crucial role in regulating brain development, emotional behavior, stress responses, and cognitive functions. This review explores the key mechanisms underlying microbiota–brain interactions, including neural pathways via the vagus nerve, neuroendocrine regulation through the hypothalamic–pituitary–adrenal axis, immune-mediated signaling, and microbial production of neurotransmitters and metabolites. Special emphasis is placed on the role of dysbiosis in the pathogenesis of mental disorders such as depression, anxiety, autism spectrum disorder, schizophrenia, and stress-related conditions. Additionally, the therapeutic potential of microbiome modulation through diet, probiotics, lifestyle interventions, and emerging psychobiotics is discussed. Understanding the gut–brain axis provides new opportunities for preventive and personalized approaches to mental health management.

Keywords: Gut–brain axis, gut microbiota, dysbiosis, mental disorders, depression, anxiety, psychobiotics, inflammation, neurotransmitters

1. Introduction

Mental disorders represent a significant global health burden, affecting hundreds of millions of individuals worldwide. Traditional models of psychiatry have primarily focused on neurochemical imbalances and genetic predisposition; however, these models alone fail to fully explain the complexity and heterogeneity of psychiatric conditions. In recent years, interdisciplinary research

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has revealed the importance of peripheral systems, particularly the gastrointestinal tract, in brain function and mental well-being.

The concept of the gut–brain axis describes a complex, bidirectional communication network linking the gastrointestinal system with the central nervous system. This network allows the brain to influence gut function and, conversely, enables gut-derived signals to modulate brain activity. Central to this interaction is the gut microbiota, a dynamic community of trillions of microorganisms that exert profound effects on host metabolism, immunity, and neurophysiology.

Advances in microbiology, neuroscience, and immunology have demonstrated that disturbances in gut microbiota composition, known as dysbiosis, may contribute to the pathogenesis of various mental disorders. Consequently, the gut microbiome has emerged as a promising target for novel therapeutic strategies in psychiatry.

2. The Gut–Brain Axis: An Overview

The gut–brain axis is a highly integrated system involving multiple biological pathways that facilitate communication between the gut and the brain.

2.1 Neural Pathways

The vagus nerve represents the primary neural connection between the gastrointestinal tract and the brain. Sensory neurons transmit information about gut microbial activity, nutrient availability, and inflammatory status to the brainstem, while efferent signals from the brain regulate intestinal motility and secretion.

2.2 Neuroendocrine Regulation

The hypothalamic–pituitary–adrenal (HPA) axis plays a central role in stress regulation. Gut microbiota modulate the development and reactivity of the HPA axis, influencing cortisol release and stress resilience. Dysregulation of this axis has been implicated in anxiety and depressive disorders.

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2.3 Immune Signaling

Approximately 70% of immune cells are located in the gut-associated lymphoid tissue. Gut microbiota interact closely with immune cells, regulating cytokine production and inflammatory responses. Chronic low-grade inflammation originating in the gut may affect brain function and behavior.

2.4 Microbial Metabolites

Gut microorganisms produce a wide range of bioactive compounds, including short-chain fatty acids (SCFAs), neurotransmitters, and vitamins, which can influence neural signaling and brain physiology.

3. Gut Microbiota and Neuroactive Compounds

Gut microbiota contribute to mental health by synthesizing and modulating neuroactive substances.

3.1 Neurotransmitter Production

Several gut bacteria are capable of producing neurotransmitters or their precursors. For example:

- Lactobacillus and Bifidobacterium species produce gamma-aminobutyric acid (GABA), an inhibitory neurotransmitter involved in anxiety regulation.
- Certain microbial strains influence serotonin metabolism; approximately 90% of the body's serotonin is produced in the gut.
- Dopamine and norepinephrine precursors can also be synthesized by gut bacteria.

These substances may act locally on enteric neurons or indirectly influence brain function through neural and immune pathways.

3.2 Short-Chain Fatty Acids

SCFAs, such as butyrate, propionate, and acetate, are produced through microbial fermentation of dietary fiber. Butyrate is particularly important for maintaining intestinal barrier integrity, reducing inflammation, and modulating gene expression via epigenetic mechanisms. SCFAs also affect microglial maturation and neuroplasticity.

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4. Dysbiosis and Mental Disorders

Dysbiosis refers to qualitative and quantitative alterations in gut microbiota composition. Increasing evidence links dysbiosis to various psychiatric and neurodevelopmental disorders.

4.1 Depression and Anxiety

Patients with depression and anxiety disorders often exhibit reduced microbial diversity and decreased abundance of anti-inflammatory bacteria such as Faecalibacterium prausnitzii. Dysbiosis may promote systemic inflammation and alter neurotransmitter metabolism, contributing to mood disturbances.

4.2 Autism Spectrum Disorder

Altered gut microbiota composition has been consistently reported in individuals with autism spectrum disorder. Gastrointestinal symptoms frequently co-occur with behavioral abnormalities, suggesting a link between gut dysfunction and neurodevelopment.

4.3 Schizophrenia and Stress-Related Disorders

Emerging studies indicate that microbiota alterations may influence dopamine signaling, immune activation, and oxidative stress pathways involved in schizophrenia and post-traumatic stress disorder.

5. Mechanisms Linking Dysbiosis to Brain Dysfunction

Several interconnected mechanisms explain how gut dysbiosis may affect mental health:

1. Increased intestinal permeability leading to translocation of bacterial components into the bloodstream.
2. Activation of systemic inflammation with elevated proinflammatory cytokines such as IL-6 and TNF-α.
3. Disruption of the blood–brain barrier, allowing inflammatory mediators to affect neural tissue.
4. Altered neurotransmitter balance and stress hormone regulation.

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These processes collectively contribute to neuroinflammation and functional brain changes.

6. Therapeutic Modulation of the Gut Microbiome

6.1 Dietary Interventions

Diet is one of the most powerful modulators of gut microbiota. Diets rich in fiber, polyphenols, omega-3 fatty acids, and fermented foods promote microbial diversity and anti-inflammatory effects.

6.2 Probiotics and Psychobiotics

Certain probiotic strains have demonstrated anxiolytic and antidepressant effects in both animal models and human studies. The term psychobiotics describes probiotics that exert beneficial effects on mental health.

6.3 Lifestyle Factors

Regular physical activity, adequate sleep, and stress management techniques such as meditation positively influence microbiota composition and reduce inflammation.

6.4 Pharmacological Considerations

Some psychotropic medications may alter gut microbiota composition. Understanding these interactions may help optimize treatment outcomes and reduce side effects.

7. Future Perspectives

Microbiome-based therapies represent a promising frontier in psychiatry. Personalized nutrition, targeted probiotics, and microbiota profiling may enable individualized treatment strategies. Although approaches such as fecal microbiota transplantation are still experimental in mental health, ongoing research continues to explore their potential.

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For a long time, the gut was simply perceived as a digestive organ, but in recent years, experts have discovered its much more profound impact on the human body—especially on emotions, mood, and even behavior. This article explores the relationship between the gut and the central nervous system, known as the "gut-brain axis." We will examine the mechanisms of this interaction, the impact of dysbiosis, and practical recommendations for maintaining mental health through microbiome correction.

What is the gut-brain axis?

The gut-brain axis is a two-way communication system between the gastrointestinal tract and the brain. It includes:

The nervous system: the primary connection is via the vagus nerve;

The hormonal system: involvement of the hypothalamic-pituitary-adrenal axis (HPA);

The immune system: approximately 70% of all immune system cells are located in the gut;

Microbiota: Gut microorganisms mediate many processes.

Together, these systems maintain homeostasis, regulate stress, sleep, mood, and even cognitive function.

The Role of Microbiota

Microbiota is the collection of microorganisms that inhabit our body, primarily the large intestine. In humans, it weighs approximately 1.5 kg and plays a key role in metabolism, immune response, and neurotransmitter synthesis.

The main types of microbes that influence mental health are:

- Bifidobacterium – reduces anxiety;
- Lactobacillus – participates in the synthesis of GABA, one of the main "anxiolytic" neurotransmitters;
- Faecalibacterium – has anti-inflammatory effects;
- Roseburi – synthesizes butyric acid, which maintains the integrity of the intestinal barrier.

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Changes in the composition of the microbiota, known as dysbiosis, can lead to inflammation, increased intestinal permeability ("leaky gut"), and ultimately impact the brain through inflammatory cytokines and neurochemical changes.

How does the microbiota influence mental health?

Scientific research shows that the microbiota may influence conditions such as:

Depression;

Anxiety disorders;

Autism;

Schizophrenia;

Post-traumatic stress disorder;

Alcoholism and drug addiction.

Recommendation: If you experience chronic anxiety, unexplained fatigue, or depression, start with a microbiome analysis and consultation with your doctor. Sometimes simple changes to diet and lifestyle can significantly improve your well-being.

Mechanisms of microbiota influence:

Neurotransmitter production: Microbes produce serotonin, dopamine, GABA, and norepinephrine—substances that influence our mood and stress levels.

Impact on the HPA axis: The microbiota regulates the release of cortisol, the stress hormone. Disruption of this axis is associated with chronic anxiety and depression.

Immune response and inflammation: Dysbiosis causes systemic inflammation, which is associated with the development of depression. Levels of proinflammatory cytokines, such as IL-6 and TNF-alpha, are elevated.

Impact on barriers: intestinal and blood-brain barriers: When the intestinal barrier is disrupted, pathogens enter the bloodstream and can cross the blood-brain barrier, causing neurological disorders.

Conclusion:

The connection between the gut and the brain is one of the most exciting and rapidly developing areas of medicine. Our "inner friends"—microbes—play a key role in shaping our mood, stress resilience, and even intelligence.

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Maintaining a healthy microbiome is becoming more than just a matter of digestion; it's an important element in the prevention and treatment of mental illness. Don't ignore your gut signals. Sometimes, simple lifestyle and dietary changes can dramatically improve your quality of life.

If you notice unexplained anxiety, fatigue, or depression, it might be worth starting with a microbiome analysis and consulting with a doctor. Remember: your gut is your second brain. Listen to it, take care of it, and it will reciprocate.

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