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HOW AN IMBALANCE IN GUT BACTERIA AFFECTS AUTISM

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YOUNG REVIEWERS:

DISLEY PRIMARY SCHOOL SCIENCE CLUB
AGES: 10–11

JANA
AGE: 15

MOHAMMAD
AGE: 15

Autism spectrum disorder (ASD) is a group of conditions related to brain development, which affect social interactions and communication. The gut and brain work together closely, and this interaction may play a role in ASD—bacteria, that live in the gut, can influence brain development and may affect ASD symptoms. To further support this gut-brain connection, most people with ASD suffer from stomach problems. This article will tell you about research indicating that gut bacteria may affect brain functions like social behavior and emotion regulation, which have been linked to a part of the brain called the amygdala. A deeper understanding of how gut bacteria, the brain, and behavior interact could lead to therapies that improve both emotional and physical symptoms in individuals with ASD.

NADA

AGE: 15

NOOR

AGE: 15

HUMAN MICROBIOTA

Living organisms, invisible to the human eye, that live in and on our bodies, such as the gut or the skin.

GUT BACTERIA AND AUTISM

We live in a world full of microbes. The **human microbiota** refers to the trillions of microorganisms, including bacteria, living in and on our bodies. Bacteria are microscopic single-celled organisms. While some bacteria cause infections and diseaQ7ses, many others are good for us, helping with digestion and immune system function. An imbalance between beneficial and harmful bacteria is linked to disorders of brain development, like autism spectrum disorder (ASD) [1]. ASD is characterized by ongoing problems with social communication and social interaction, and symptoms include a number of common behaviors (Figure 1). Research has shown that a lack of beneficial bacteria, especially in the gut, can influence brain functions and social behaviors. These bacterial differences are linked to stomach pain, constipation, and diarrhea, which are common in individuals with ASD [1]. However, we still do not fully understand the relationship between gut bacteria and autism.

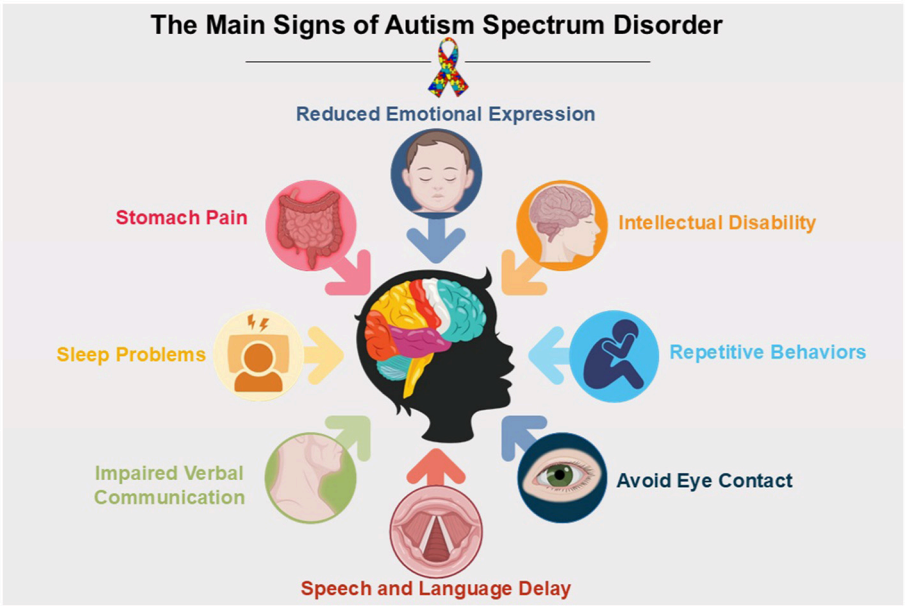

Figure 1

Figure 1

Some children with ASD start showing signs at only a few months old. Others appear to develop typically for the first few months or years before symptoms emerge. Early symptoms of ASD include reduced emotional and social expressions, mild to severe intellectual disability, repetitive behaviors or restricted range of interests, avoiding eye contact during conversations, delayed speech or language development, difficulties with verbal and nonverbal communication, sleep disturbances, and stomach pain (Figure created with BioRender.com).

WHAT IS THE GUT MICROBIOTA?

The gut microbiota plays a vital role in the human body. Human bodies consist of about 30 trillion human cells and 39 trillion bacteria [2]! The fact that our bodies have more bacteria than human cells can change our understanding of brain health and the role of the microbiota in influencing brain processes, emotional wellbeing, and behavior. Gut microbes help with digestion by breaking down food, particularly complex carbohydrates like bread, rice, and vegetables. These microbes produce substances called short-chain fatty acids, which provide energy to gut cells, support the immune system,

and reduce inflammation [3]. The gut microbiota also makes certain important vitamins (Figure 2). Many vitamin deficiencies can disrupt a healthy gut, and when these imbalances occur, they may contribute to conditions associated with ASD.

Figure 2

The gut microbiota makes certain vitamins that might play a role in ASD if their levels are out of balance (Figure created with BioRender.com).

Vitamin	Role in the Human Body	Potential Effects of Imbalance in ASD
B_9	Proper nervous system function, balanced neurotransmitter levels	Developmental delays, irritability, immune dysfunction
B_{12}	Maintain the health of nerve tissue, brain function, and red blood cells	Developmental delays, mood disorders
B_6	Involved in neurotransmitter synthesis, proper brain development	Impaired immune system
D	Improvement of gut microbiota	Impairment of central nervous system development, getting sick often
A	Proper brain development, support the immune system	Stomach problems, irritability, mood disorders

Figure 2

To illustrate how gut health can impact individuals with ASD, let us look at the case of a preschool girl named Ella. Ella is a 5-year-old with ASD who frequently suffers from stomach pain. Her stomach pain is linked to issues with social communication. While ASD is a life-long condition, certain medical treatments can reduce ASD symptoms and improve overall wellbeing. Ella was referred to a dietitian who prescribed **probiotics** to help relieve her abdominal symptoms. Probiotics are good live bacteria that support health and may prevent certain disorders. They are found in dietary supplements and fermented foods like yogurt and cheese. In Ella's case, she takes them as a dietary supplement. She started taking 3 capsules of *Bifidobacterium longum*, a beneficial type of bacteria, each day for 4 months, which decreased the severity of her ASD and stomach symptoms. The *Bifidobacterium longum* reduced the harmful bacteria in her gut and improved her social skills.

PROBIOTICS

Good live bacteria that support health, may prevent certain disorders, and are found in dietary supplements and fermented foods.

CAN THE GUT MICROBIOME AFFECT THE BRAIN?

The important system linking the gut microbiome to the brain is called the **gut-brain axis**. The brain is a complex organ that controls all of our actions and thoughts and processes the input from our senses. The brain contains about 86 billion neurons, which are cells specialized in transmitting signals and processing information [4]. Through the spinal cord, the brain communicates with all other bodily systems, including the endocrine system, which helps regulate bodily functions,

GUT-BRAIN AXIS

A network of nerves that connect the brain and gut and send signals back and forth.

like stress and mood, through hormone secretion, and the immune system, which defends the body against germs and supports healing [1]. These bodily systems exchange signals via the **vagus nerve**, which transmits information from the body's organs to brain regions like the **amygdala** (Figure 3).

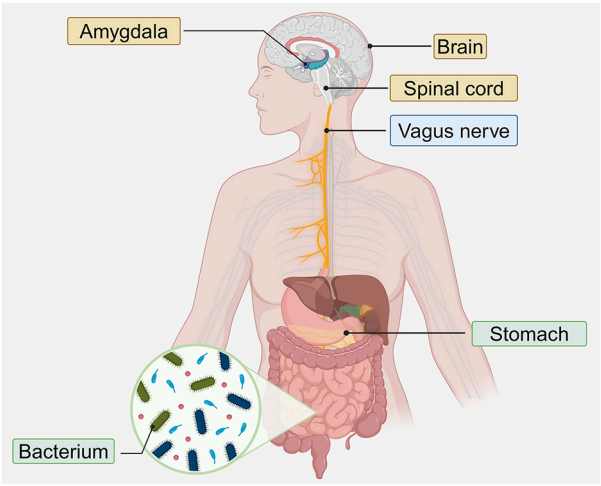

Figure 3

The vagus nerve and spinal cord connect the digestive system to the brain via the gut-brain axis. The gut microbiota is made up of trillions of tiny organisms that help break down food, absorb nutrients like B vitamins, and keep the immune system strong. In children with ASD, the gut microbiota is out of balance, with fewer good bacteria and more harmful ones, which can cause stomach problems. This imbalance may also affect how the brain works, influencing emotions, behaviors, and social skills (Figure created with BioRender.com).

WHAT WE KNOW ABOUT THE GUT MICROBIOME AND ASD

How does an imbalance in gut bacteria affect social behavior in ASD? The amygdala is likely to play an important role. The amygdala is an almond-shaped brain region that is essential for emotional processing, decision-making, and social interaction. Abnormal enlargement of the amygdala in ASD may indicate increased activity, which could disrupt normal emotion processing and control over behavior [5]. The microbiota is vital for the normal development of the amygdala. When people with ASD experience anxiety and stress, their amygdalae may be overly activated.

Signals from the gut microbiota may reach the amygdala by traveling through the vagus nerve. A surgery called a **vagotomy**, which involves removing all or part of the vagus nerve, may reduce the gut's ability to send these signals to the amygdala, changing the brain's perception of gut health [5]. Vagotomy is used to treat stomach issues, but severing the vagus nerve can also eliminate the helpful effects of certain probiotics [5]. For example, vagotomy prevents the beneficial effect of *Bifidobacterium longum* in reducing repetitive behaviors in ASD. This means that a healthy connection between the gut and brain is vital, with the vagus nerve acting as a bridge. Probiotics use this pathway to send signals that can ease social challenges in ASD. The second pathway for microbial signals to reach the amygdala is through the spinal cord. Spinal nerve endings in the gut detect signals from

VAGUS NERVE

A group of nerve fibers that connects the brain to many of the body's organs, such as the heart and gut.

AMYGDALA

A small, almond-shaped structure in the brain that regulates emotional processing, decision-making, and social interactions.

VAGOTOMY

A surgical procedure that involves cutting or removing part of the vagus nerve.

microbes, which then travel to the amygdala by moving up the nerves into the brain [5].

Gut microbes produce chemicals called **neurotransmitters**, which can affect the brain through the bloodstream. One of these neurotransmitters is **serotonin**, which is involved in mood, appetite, and thinking processes [1]. About 90% of the body's serotonin is produced in the gut [6]. Changes in serotonin production can cause anxiety [1]. Probiotics can change serotonin levels in brain regions connected to the amygdala [5]. This is crucial because serotonin helps regulate the amygdala's activity and responses to emotions, reducing the risk of ASD symptoms.

NEUROTRANSMITTER

A chemical substance released by one nerve cell and received by another, enabling communication between nerve cells.

SEROTONIN

A type of neurotransmitter that carries messages between nerve cells in the brain and throughout the body.

FUTURE RESEARCH

Since children with ASD may have a different mix of bacteria in their guts compared to children without ASD, understanding individual differences in gut microbiota composition could lead to personalized treatments that could ease some of the difficulties experienced by people with ASD. Future research could aim to identify specific bacteria related to amygdala issues and develop treatments based on these findings [5]. Further, providing the appropriate nutrients both before and after birth could help reduce the symptoms of ASD.

In summary, the human microbiota plays an important role in keeping us healthy. A balanced microbiome helps our bodies absorb nutrients, digest food properly, and support the immune system. But when the microbiome is out of balance, it can lead to different health problems, including ASD. Scientists are working hard to explore new treatments like probiotics. Learning about these tiny helpers in our gut could change the way we think about health—so stay curious and keep exploring!

AI TOOL STATEMENT

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

DISLEY PRIMARY SCHOOL SCIENCE CLUB, AGES: 10–11

The Year 6 Science Club at Disley Primary School took the opportunity to learn about neuroscience by accepting the challenge of reviewing an article for Frontiers for Young Minds. We loved being a part of the scientific process and learning about the connection between the gut and the brain and how we can keep them both happy and healthy.

JANA, AGE: 15

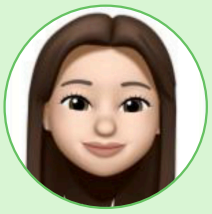
Hi I am Jana a 15 year old girl with a growing passion for discovering new and interesting things which is how I spend most of my free time, I have been a ballet dancer for more than 11 years now, and I find joy in helping others which is why I have always wanted to become a doctor!

MOHAMMAD, AGE: 15

My name is Mohammad, and I am a Palestinian with a passion for working out and exploring my rich cultural and historical heritage. I am committed to becoming an active member of the Jerusalemite community, where I feel I truly belong. By working hand in hand with my community during challenging times and studying the practices we experience, I aim to contribute positively and make a meaningful impact.

NADA, AGE: 15

I am Nada. I like painting and music, specifically playing the piano. These hobbies help me stay calm and relieve stress. What intrigues me about these activities is their relation to emotions. I am deeply interested in psychology and mental health. I want to understand people and their actions on a deeper level, which helps me discover more about the world around me.



NOOR, AGE: 15

I am Noor. I have always been fascinated by how things work, especially when it comes to science and technology. I am a big adrenaline lover and always up for an adventure, whether it is trying a new sport or exploring the outdoors, though my calm nature often surprises people who learn this about me. I have been passionate about sports since I was young, and I believe that staying active helps fuel my curiosity and drive to learn more about the world around me.

AUTHORS

LIDYA K. YASSIN

Lidya Kasem is a research assistant in the Department of Anatomy at the College of Medicine and Health Sciences, United Arab Emirates University. She has a profound interest in neural networks in the brain that facilitate the brain's constant rewiring. Lidya advocates for individuals with rare genetic diseases by exploring the mechanisms underlying these conditions.

SHAMSA ALSHAMSI

I am Shamsa, a 3rd-year medical student at the College of Medicine & Health Sciences, United Arab Emirates University. I am passionate about and committed to healthcare, with a particular interest in neurology and pediatrics. My academic journey is further enriched by my active participation in research projects, focusing on advancing various fields of medicine, including anatomy, genetics, and pharmacology. I have gained valuable clinical exposure by shadowing multiple pediatric cardiologists, allowing me to develop key skills and insights. Dedicated to lifelong learning, I aspire to provide compassionate patient care and contribute to medical advancements throughout my future career as a physician.

FATIMETOU HREIMOU

I am Fatimetou Hreimou, a recent graduate with a bachelor's degree in cellular and molecular biology from the College of Science at the United Arab Emirates University. I love learning about how nature works and how living things grow. I am especially curious about how our surroundings can affect us. With a passion for science, philosophy, and exploration, I want to help people understand more about the world through science!

SALEM ALYAMMAHI

Salem Alyammahi is a senior student in speech-language pathology at the UAEU. He has research interests in autism spectrum disorder (ASD) and is currently involved in developing one of the ASD assessments. He believes that giving has no limits and that contributing to others' wellbeing is a profound and endless source of fulfillment. He is particularly passionate about improving the lives of individuals with ASD, advocating for their inclusion and providing support to help them achieve their full potential.

MOHAMMAD I. K. HAMAD

Greetings. I am Dr. Mohammad I. K. Hamad, currently serving as an assistant professor of human anatomy at the Medical Faculty of the United Arab Emirates University. I have been engaged in research on the impact of external factors on brain architecture for two decades. My laboratory is currently focused on investigating the gut-brain axis, with the objective of identifying beneficial bacterial strains that may play a role in the prevention of diseases of the nervous system. *m.hamad@uaeu.ac.ae