The Gut-Brain Connection: Metabolites from the Microbiome in Major Depressive Disorder

Major depressive disorder (MDD) is one of the most disabling mental health conditions worldwide, affecting millions of people with complex and often treatment-resistant symptoms. Emerging research has established a strong bidirectional communication network between the gut and brain, termed the gut-brain axis, where gut microbial metabolites play a crucial role. This report synthesizes current evidence connecting gut microbiota-derived metabolites to the pathophysiology and potential treatment of major depressive disorder.

The Microbiota-Gut-Brain Axis in Depression

The gut microbiota, consisting of trillions of microorganisms with collective genomes containing 100-150 times more genetic information than the human genome, has co-evolved with humans to significantly impact host physiology[19]. These microorganisms produce numerous metabolites that can exert local effects in the gastrointestinal environment, interact with the gut wall, or enter systemic circulation to reach distant organs including the brain[15][19].

Dysbiosis, characterized by compositional and functional changes in gut microbiota, has been increasingly associated with the onset and progression of depression through its regulation of the gut-brain axis[1]. This connection is supported by both preclinical and clinical studies showing that perturbations in gut microbiota development can negatively impact neurogenesis, axonal growth, dendritic development, and synaptogenesis, all of which can contribute to mental health disorders later in life[19].

Early-life colonization by gut microbiota appears essential for normal hypothalamic-pituitary-adrenal (HPA) axis development and appropriate neuroendocrine responses to stress[19]. Research shows that germ-free mice exhibit exaggerated HPA axis responses to restraint stress, characterized by elevated stress hormones and reduced brain-derived neurotrophic factor (BDNF) expression in the cortex and hippocampus[19].

Key Gut Metabolites Implicated in Depression

Short-Chain Fatty Acids (SCFAs)

SCFAs-primarily acetate, butyrate, and propionate-are organic compounds produced through anaerobic fermentation of indigestible dietary carbohydrates in the cecum and colon[19]. These metabolites have emerged as significant factors in depression pathophysiology:

- Administration of the three most abundant SCFAs (acetate, butyrate, and propionate) has been shown to alleviate depressive symptoms in mice[19]

- Depletion of butyrate, acetate, and propionate has been reported in MDD patients[19]

- Sodium butyrate specifically has demonstrated antidepressant effects in animal models of depression and mania[16]

- Butyrate-producing bacteria exert beneficial effects on depressive symptoms through their anti-inflammatory functions[5]

The antidepressant effects of butyrate appear to operate through epigenetic mechanisms, with animal studies showing that butyrate accelerates BDNF expression in the hippocampus via inhibition of histone deacetylase, improving depressive behavior in stress-induced depression models[5].

Tryptophan Metabolites

Tryptophan metabolism represents one of the most extensively studied pathways linking gut microbiota to depression. This essential amino acid serves as a precursor for several neuroactive compounds through three major pathways:

1. **Serotonin pathway**: Tryptophan is the sole precursor for serotonin (5-HT), a neurotransmitter traditionally implicated in depression[13]. The serotonin hypothesis of

depression, introduced more than 50 years ago, remains a cornerstone of biological theories of depression and informs many current antidepressant treatments[13].

2. **Kynurenine pathway**: Mounting evidence suggests kynurenine pathway (KP) metabolites link inflammation and depression through effects on brain glutamate receptors[7]. Path analysis has revealed a directional association extending from plasma inflammatory markers to plasma kynurenines to cerebrospinal fluid (CSF) kynurenines, suggesting plasma KP metabolites mediate inflammation-associated depressive symptoms via central nervous system KP metabolites[7].

3. **Indole pathway**: Indole, produced by gut microbiota from tryptophan through the tryptophanase enzyme encoded by the *tnaA* gene, affects brain function and behavior[6]. Research suggests that individuals whose gut microbiota is highly prone to produce indole could be more susceptible to developing anxiety and mood disorders[6]. When indole production was experimentally increased in rats, it led to decreased motor activity, accumulation of neurodepressant oxidized derivatives (oxindole and isatin) in the brain, and activation of the vagus nerve[6].

Research has demonstrated that tryptophan metabolism plays a crucial role in the crosstalk between gut microbiota and the brain in depression[3]. In particular, the phylum Firmicutes, especially genus *Lactobacillus*, appears involved in the onset of depression through regulation of tryptophan metabolism[3].

Bile Acids

Bile acids (BAs) are steroid acids synthesized in the liver from cholesterol and further processed by gut bacterial enzymes, representing another metabolic pathway requiring both host and gut microbiome enzymatic processes[14]. Studies have found:

- Gut microbiota and bile acid metabolism are disturbed in MDD patients, with significant correlation between the two[8]

- Chronic unpredictable mild stress significantly promotes the deconjugation of conjugated bile acids and secondary bile acid biosynthesis in animal models[17]

- Changes in family *Ruminococcaceae* abundance following chronic stress increase biosynthesis of deoxycholic acid (DCA), an unconjugated secondary bile acid in the intestine[17]

- Secondary bile acid levels in the feces positively correlate with *Ruminococcaceae_UCG-010*, *Ruminococcus*, and *Clostridia_UCG-014* abundance[17]

In patients with MDD, bile acid profiles representing changes in gut microbiome compositions are associated with higher anxiety levels and increased probability of first-line treatment failure[14].

Lactate

Lactate, a metabolite produced during exercise and by certain gut bacteria, has demonstrated antidepressant properties. Research shows lactate promotes resilience to stress and acts as an antidepressant by restoring hippocampal class I histone deacetylase (HDAC) levels and activity, specifically HDAC2/3[9].

In a paradigm where lactate was administered after depression establishment, it behaved as an antidepressant by regulating HDAC5 rather than HDAC2/3 levels[9]. This suggests lactate mimics exercise's beneficial effects on depression through epigenetic mechanisms.

Other Metabolites

Additional metabolites produced or modulated by gut microbiota may contribute to depression pathophysiology. For instance, emerging evidence points to an essential role of vitamins in the interaction between the gut microbiome and mitochondrial energy production in depression[10].

Mechanisms Linking Gut Metabolites to Depression

Multiple mechanisms exist through which gut microbial metabolites affect depressive behavior:

Direct Stimulation of Central Receptors

Gut-derived metabolites that cross the blood-brain barrier can directly bind to specific receptors in the central nervous system, influencing neurological function and behavior[15][19]. For example, some microbe-produced neurotransmitters may influence emotional behavior by binding specific central receptors[19].

Peripheral Stimulation of Neural, Endocrine, and Immune Mediators

Gut metabolites can stimulate peripheral receptors on neural or immune cells, triggering signaling cascades that ultimately affect brain function[15][19]. The vagus nerve appears to be a key mediator in this process, as demonstrated by increased eye blinking frequency and c-Fos protein expression in the dorsal vagal complex following indole administration[6].

Epigenetic Regulation

Metabolites like butyrate and lactate can regulate gene expression through epigenetic mechanisms, particularly histone modifications[15]. Butyrate's antidepressant effects appear to operate through inhibition of histone deacetylase, accelerating BDNF expression in the hippocampus[5]. Similarly, lactate promotes resilience to stress by restoring hippocampal class I histone deacetylase levels and activity[9].

Inflammatory Pathways

Gut dysbiosis can influence depression through altered inflammatory responses. Studies suggest that Firmicutes, especially family Lachnospiraceae, might contribute to depression onset by affecting host inflammation levels[4]. Correlation analysis has shown significant relationships between differential operational taxonomic units (predominantly from Firmicutes) and inflammation-related factors[4].

Dysbiosis Patterns in Depression

Changes in gut microbial composition have been consistently observed in depression:

- 16S rRNA gene sequencing analysis has identified numerous differential operational taxonomic units (OTUs) between MDD patients and healthy controls[3][4]

- A majority (approximately 60.9%) of differential OTUs belong to the phylum Firmicutes[4]

- Alpha-diversity analyses have found that Simpson and Pielou evenness indices are significantly higher in healthy controls compared to MDD patients[8]

- Beta-diversity analyses confirm distinct microbial profiles between depressed and non-depressed individuals[8]

Linear discriminant analysis effect size (LEfSe) analysis has identified specific bacterial strains that differ significantly between MDD patients and healthy controls[8]. Importantly, many of these differential microbes correlate with both metabolic changes and depression severity.

In animal models, chronic social defeat stress successfully induces depressive-like behaviors and significantly alters gut microbiota compositions compared to controls[3]. These changes predominantly affect the phylum Firmicutes, with particularly strong correlations between genus *Lactobacillus*, tryptophan metabolism, and depression symptoms[3].

Therapeutic Implications

The understanding that gut metabolites influence depression pathophysiology opens up new avenues for treatment:

Microbial-Targeted Therapeutics

Emerging research suggests that modulating the gut microbiome offers a promising approach to treating depression[1]. Potential microbial-targeted therapeutics include:

- Dietary interventions focusing on prebiotic fibers to promote beneficial bacterial growth
- Fecal microbiota transplantation to restore healthy microbial communities
- Probiotics, particularly *Lactobacillus* and *Bifidobacterium* species with demonstrated beneficial effects[13]
- Prebiotics that selectively promote growth of beneficial bacteria
- Synbiotics (combinations of pre- and probiotics)
- Postbiotics that utilize beneficial bacterial metabolites directly[1]

Focus on Specific Metabolic Pathways

Targeting specific metabolic pathways disrupted in depression represents another therapeutic approach:

- Tryptophan supplementation, either alone or combined with other antidepressants, may help increase serotonin levels in the brain[13]
- Sodium butyrate administration has shown antidepressant effects in animal models[16]
- Lactate supplementation may promote resilience to stress through epigenetic mechanisms[9]

- Gut microbiome-directed therapies for MDD characterized by gut dysbiosis show promise, particularly for patients with altered bile acid profiles associated with treatment resistance[14]

Elucidating the mechanisms through which gut metabolites influence depression is essential for developing novel therapeutic strategies that harness their beneficial psychotropic effects[15].

Conclusion

The evidence connecting gut metabolites to major depressive disorder has grown substantially in recent years, revealing complex relationships between microbial metabolism and brain function. Short-chain fatty acids, tryptophan metabolites, bile acids, lactate, and other gut-derived compounds appear to influence depression through multiple mechanisms, including direct receptor stimulation, peripheral neural and immune activation, and epigenetic regulation.

Dysbiosis patterns in depression consistently implicate specific bacterial phyla, particularly Firmicutes, which mediate many of the metabolic changes observed. Understanding these connections opens promising avenues for novel depression treatments, from microbial-targeted therapeutics to metabolic pathway modulation.

Future research should continue exploring the detailed mechanisms through which gut metabolites influence brain function in depression, with particular attention to individual differences in microbial composition and metabolism that may explain varying susceptibility to depression and treatment response. As our understanding of the microbiota-gut-brain axis grows, so too does the potential for innovative, personalized approaches to managing this prevalent and debilitating condition.

Sources

[1] Gut microbiota and its metabolites in depression: from pathogenesis ...
https://pubmed.ncbi.nlm.nih.gov/36963238/

[2] How Short-Chain Fatty Acids Affect Health and Weight - Healthline
https://www.healthline.com/nutrition/short-chain-fatty-acids-101

[3] Tryptophan metabolism as bridge between gut microbiota and brain ...
https://pmc.ncbi.nlm.nih.gov/articles/PMC9999000/

[4] Gut Microbiota-Related Inflammation Factors as a Potential ...
https://www.frontiersin.org/journals/cellular-and-infection-microbiology/articles/10.3389/fcimb.2022.831186/full

[5] How Microbes Affect Depression: Underlying Mechanisms via the ...
https://pmc.ncbi.nlm.nih.gov/articles/PMC8835211/

[6] Indole, a Signaling Molecule Produced by the Gut Microbiota ...
https://pubmed.ncbi.nlm.nih.gov/29686603/

[7] Associations among peripheral and central kynurenine pathway ...
https://www.nature.com/articles/s41386-020-0607-1

[8] Abnormal gut microbiota and bile acids in patients with first-episode ...
https://pubmed.ncbi.nlm.nih.gov/35445772/

[9] Lactate is an antidepressant that mediates resilience to stress by ...
https://pubmed.ncbi.nlm.nih.gov/30647450/

[10] Vitamin-mediated interaction between the gut microbiome and ...
https://www.sciencedirect.com/science/article/pii/S2666354624000681

[11] Gut microbiota and its metabolites in depression - ScienceDirect.com
https://www.sciencedirect.com/science/article/pii/S2352396423000920

[12] Butyrate emerges as a crucial effector of Zhi-Zi-Chi decoctions to ...
https://www.sciencedirect.com/science/article/pii/S0753332222002505

[13] Tryptophan metabolites in depression: Modulation by gut microbiota
https://pmc.ncbi.nlm.nih.gov/articles/PMC9510596/

[14] Gut Microbiome-Linked Metabolites in the Pathobiology of Major ...
https://pubmed.ncbi.nlm.nih.gov/35937867/

[15] Gut microbial metabolites in depression: understanding the ...
https://pmc.ncbi.nlm.nih.gov/articles/PMC6780009/

[16] Gut microbiome-wide association study of depressive symptoms
https://www.nature.com/articles/s41467-022-34502-3

[17] Gut Microbiota-Mediated Elevated Production of Secondary Bile ...
https://www.frontiersin.org/journals/pharmacology/articles/10.3389/fphar.2022.837543/full

[18] Gut microbiota and its metabolites in depression - TheLancet.com
https://www.thelancet.com/pdfs/journals/ebiom/PIIS2352-3964(23)00092-0.pdf

[19] Gut microbial metabolites in depression: understanding the ...
http://microbialcell.com/researcharticles/2019a-caspani-microbial-cell/

[20] Potential role of gut microbiota in major depressive disorder: A review
https://www.sciencedirect.com/science/article/pii/S2405844024091886

[21] Features of gut microbiota and short-chain fatty acids in patients with ...
https://www.frontiersin.org/journals/psychology/articles/10.3389/fpsyg.2023.1088268/full

[22] Tryptophan Metabolism: A Link Between the Gut Microbiota and Brain
https://www.sciencedirect.com/science/article/pii/S2161831322002952

[23] Biomarkers for major depressive disorder | JIR - Dove Medical Press
https://www.dovepress.com/gut-microbiota-derived-inflammation-related-serum-metabolites-as-poten-peer-reviewed-fulltext-article-JIR

[24] Gut microbiota composition in depressive disorder - Nature
https://www.nature.com/articles/s41398-023-02670-5

[25] Gut microbiota-derived short-chain fatty acids and depression
https://pmc.ncbi.nlm.nih.gov/articles/PMC10882305/

[26] Neuroprotective Natural Products' Regulatory Effects on Depression ...
https://pubmed.ncbi.nlm.nih.gov/36014776/

[27] Depression-associated gut microbes, metabolites and clinical trials
https://pmc.ncbi.nlm.nih.gov/articles/PMC10864537/

[28] Systematic Review of Gut Microbiota and Major Depression - Frontiers
https://www.frontiersin.org/journals/psychiatry/articles/10.3389/fpsyt.2019.00034/full

[29] Fecal Short-Chain Fatty Acid Ratios as Related to Gastrointestinal ...
https://pmc.ncbi.nlm.nih.gov/articles/PMC8428857/

[30] and anxiety-like behavior in mice: The potential involvement of gut ...
https://www.sciencedirect.com/science/article/abs/pii/S0963996922003465

[31] Microbes and mood: innovative biomarker approaches in depression
https://www.sciencedirect.com/science/article/abs/pii/S1471491424002417

[32] Brain–gut–microbiota axis in depression: A historical overview and ...
https://www.sciencedirect.com/science/article/pii/S0361923022000375

[33] Short Term Intrarectal Administration of Sodium Propionate Induces ...
https://pubmed.ncbi.nlm.nih.gov/30319461/

[34] Protective Effect of Hop Ethyl Acetate Extract on Corticosterone ...
https://pubs.acs.org/doi/10.1021/acschemneuro.4c00081

[35] Bacterial Butyrate in Parkinson's Disease Is Linked to Epigenetic ...
https://movementdisorders.onlinelibrary.wiley.com/doi/10.1002/mds.29128

[36] Short Term Intrarectal Administration of Sodium Propionate Induces ...
https://www.frontiersin.org/journals/psychiatry/articles/10.3389/fpsyt.2018.00454/full

[37] Investigation of anti-depression effects and potential mechanisms of ...
https://www.frontiersin.org/journals/pharmacology/articles/10.3389/fphar.2023.1239197/full

[38] and Depression-like Phenotypes Generated by Fecal Engraftment of ...
https://pubs.acs.org/doi/10.1021/acschemneuro.3c00727

[39] Butyrate- and Beta-Hydroxybutyrate-Mediated Effects of ... - MDPI
https://www.mdpi.com/2075-1729/14/7/787

[40] Gut microbiota and its metabolites in depression: from pathogenesis ...
https://www.thelancet.com/journals/ebiom/article/PIIS2352-3964(23)00092-0/fulltext

[41] Acetate supplementation produces antidepressant-like effect via ...
https://www.sciencedirect.com/science/article/abs/pii/S016503272033055X

[42] Indole, a Signaling Molecule Produced by the Gut Microbiota ...
https://www.frontiersin.org/journals/neuroscience/articles/10.3389/fnins.2018.00216/full

[43] Peripheral and central kynurenine pathway abnormalities in major ...
https://pubmed.ncbi.nlm.nih.gov/34999196/

[44] Indole-3-propionic acid inhibits gut dysbiosis and endotoxin leakage ...
https://www.nature.com/articles/s12276-019-0304-5

[45] Indole Acetic Acid Exerts Anti-Depressive Effects on an Animal ...
https://pmc.ncbi.nlm.nih.gov/articles/PMC9737131/

[46] Identification of Gut Microbiome Signatures Associated with Indole ...
https://www.mdpi.com/2218-273X/14/6/623

[47] The kynurenine pathway in major depressive disorder, bipolar ...
https://pmc.ncbi.nlm.nih.gov/articles/PMC10668321/

[48] Gut microbiome-derived indole-3-carboxaldehyde regulates stress ...
https://www.sciencedirect.com/science/article/pii/S1043661825000799

[49] 3-indoleacetic acid (3-IAA) – Exploring its impact on human health ...
https://biocrates.com/3-indoleacetic-acid-3-iaa/

[50] Indole derivatives ameliorated the methamphetamine-induced ...
https://www.tandfonline.com/doi/full/10.1080/19490976.2025.2470386?src=

[51] The kynurenine and serotonin pathway, neopterin and biopterin in ...
https://www.frontiersin.org/journals/psychiatry/articles/10.3389/fpsyt.2024.1347178/full

[52] [PDF] Association of indolepropionic acid and depression symptoms ...
https://erepo.uef.fi/bitstreams/1b86f2c7-f634-47a4-b9fa-f57a70d6a8cb/download

[53] 3-Indoleacetic Acid | Rupa Health https://www.rupahealth.com/biomarkers/3-indoleacetic-acid

[54] Vitamin-mediated interaction between the gut microbiome and ...
https://pubmed.ncbi.nlm.nih.gov/38974216/

[55] Evidence and Mechanism of Bile Acid–Mediated Gut-Brain Axis in ...
https://www.sciencedirect.com/science/article/pii/S0002944024004127

[56] Clinical Significance and Potential Role of Trimethylamine N-Oxide ...
https://pmc.ncbi.nlm.nih.gov/articles/PMC10392962/

[57] Peripheral administration of lactate produces antidepressant-like ...
https://www.nature.com/articles/mp2016179

[58] Choline in anxiety and depression: the Hordaland Health Study
https://pubmed.ncbi.nlm.nih.gov/19656836/

[59] Gut Microbiota in Anxiety and Depression - PubMed Central
https://pmc.ncbi.nlm.nih.gov/articles/PMC10146621/

[60] TGR5 deficiency-induced anxiety and depression-like behaviors
https://www.sciencedirect.com/science/article/abs/pii/S0165032723012533

[61] Sex-Specific Associations of Trimethylamine-N-Oxide and Zonulin ...
https://onlinelibrary.wiley.com/doi/10.1155/2020/7897240

[62] Exercise, lactate and depression: what's the link? - BioTechniques
https://www.biotechniques.com/biochemistry/exercise-lactate-and-depression-whats-the-link/

[63] Brain Choline in Major Depression: A Review of the Literature
https://pubmed.ncbi.nlm.nih.gov/29174766/

[64] Research Progress on the Mechanism of Bile Acids and Their ...
https://www.mdpi.com/1422-0067/26/9/4023

[65] Folate and depression—a neglected problem - PMC
https://pmc.ncbi.nlm.nih.gov/articles/PMC1810582/

[66] Vitamin D, Depressive Symptoms, and Covid-19 Pandemic - Frontiers
https://www.frontiersin.org/journals/neuroscience/articles/10.3389/fnins.2021.670879/full

[67] Depression, the Gut Microbiome, and Vitamins - Psychology Today
https://www.psychologytoday.com/us/blog/advancing-psychiatry/202405/depression-the-gut-microbiome-and-vitamins

[68] Nutrition and Depression: the Role of Folate - Oxford Academic
https://academic.oup.com/nutritionreviews/article-abstract/55/5/145/1813961

[69] The potential role of vitamin D supplementation as a gut microbiota ...
https://www.nature.com/articles/s41598-020-77806-4

[70] Critical Review of the Cross-Links Between Dietary Components ...
https://www.mdpi.com/1422-0067/26/2/614

[71] Post-weaning folate deficiency induces a depression-like state via ...
https://www.sciencedirect.com/science/article/pii/S1347861320300219

[72] Vitamin D protects against depression: Evidence from an umbrella ...
https://www.sciencedirect.com/science/article/pii/S1043661822005515

[73] Treatment of depression: time to consider folic acid and vitamin B12
https://journals.sagepub.com/doi/10.1177/0269881105048899

[74] Vitamin D in Depression: A Potential Bioactive Agent to Reduce ...
https://www.mdpi.com/2072-6643/15/7/1765

[75] Low vitamin B12 but not folate is associated with incident depressive ...
https://www.cambridge.org/core/journals/british-journal-of-nutrition/article/low-vitamin-b12-but-not-folate-is-associated-with-incident-depressive-symptoms-in-communitydwelling-older-adults-a-4year-longitudinal-study/B1EA518340197FA07B97FF04766F6E22

[76] Vitamin D metabolites and the gut microbiome in older men - Nature
https://www.nature.com/articles/s41467-020-19793-8

[77] [PDF] Effects of butyrate on depressive symptoms and affect in depression
https://onderzoekmetmensen.nl/en/node/57116/pdf

[78] Intravenous administration of sodium propionate induces ... - Nature
https://www.nature.com/articles/s41598-020-77085-z

[79] Depressant action of acetate upon the human cardiovascular system
https://pubmed.ncbi.nlm.nih.gov/589878/

[80] The gut microbiota metabolite indole increases emotional responses ...
https://www.sciencedirect.com/science/article/abs/pii/S0306453020301694

[81] The role of the indoles in microbiota-gut-brain axis and potential ...
https://www.sciencedirect.com/science/article/abs/pii/S0028390823002800

[82] Indoxyl sulfate, a gut microbiome-derived uremic toxin, is associated ...
https://www.nature.com/articles/s41598-021-99845-1

[83] Decreased gut microbiome-derived indole-3-propionic acid ...
https://pubmed.ncbi.nlm.nih.gov/40058066/

[84] Indole Acetic Acid Exerts Anti-Depressive Effects on an Animal ...
https://pubmed.ncbi.nlm.nih.gov/36501051/

[85] Gut–microbiota–brain axis by bile acids in depression
https://onlinelibrary.wiley.com/doi/10.1111/pcn.13370

[86] Gut Microbiome-Linked Metabolites in the Pathobiology of Major ...
https://www.frontiersin.org/journals/neuroscience/articles/10.3389/fnins.2022.937906/full

[87] Trimethylamine-N oxide enhances post-stroke depression ...
https://journals.sagepub.com/doi/abs/10.1177/09603271241306396

[88] Anyone else get intensely depressed after taking choline? - Reddit
https://www.reddit.com/r/Supplements/comments/xwcqzy/anyone_else_get_intensely_depressed_after_taking/

[89] Gut microbiota and its metabolites in depression - ScienceDirect.com
https://www.sciencedirect.com/science/article/pii/S2352396423000920

[90] How your gut microbiome is linked to depression and anxiety - CAS
https://www.cas.org/resources/cas-insights/how-your-gut-microbiome-linked-depression-and-anxiety

[91] A Reciprocal Link Between Gut Microbiota, Inflammation and ...
https://www.frontiersin.org/journals/neuroscience/articles/10.3389/fnins.2022.852506/full

[92] Folate in Depression: Efficacy, Safety, Differences in Formulations ...
https://www.psychiatrist.com/jcp/folate-depression-efficacy-safety-differences-formulations/

[93] Vitamin D and Depression in Women: A Mini-review - PMC
https://pmc.ncbi.nlm.nih.gov/articles/PMC7327938/

[94] Human Gut Microbiota for Diagnosis and Treatment of Depression
https://www.mdpi.com/1422-0067/25/11/5782