

body's response to intestinal-derived damage. Therefore, the combined effect of genetics, environment and gut microbiota determines the complex pathogenesis of Parkinson's disease. In-depth study of these interrelationships is of great significance for the prevention and treatment of Parkinson's disease (Klann et al., 2022).

5 Early Diagnosis and Biomarkers Based on the Gut-brain Axis

5.1 Overview of fecal microbiota, metabolites and intestinal biopsy related indicators

Studies have found that the composition and function of the gut microbiota in PD patients are significantly different from those in healthy individuals, manifested as a reduction in butyric acidogenic bacteria, an increase in Akkermansia and Bilophila, the latter of which can serve as a potential diagnostic marker (Figure 2) (Zhao et al., 2024). These changes are often accompanied by a reduction in metabolites such as short-chain fatty acids in feces, which may exacerbate intestinal barrier damage and neuroinflammation (Tan et al., 2020; Nishiwaki et al., 2024). Fecal metagenomic and metabolomic analyses have a strong ability to distinguish PD, and the area under the curve (AUC) of some gene marker combinations can exceed 0.9 (Qian et al., 2020).

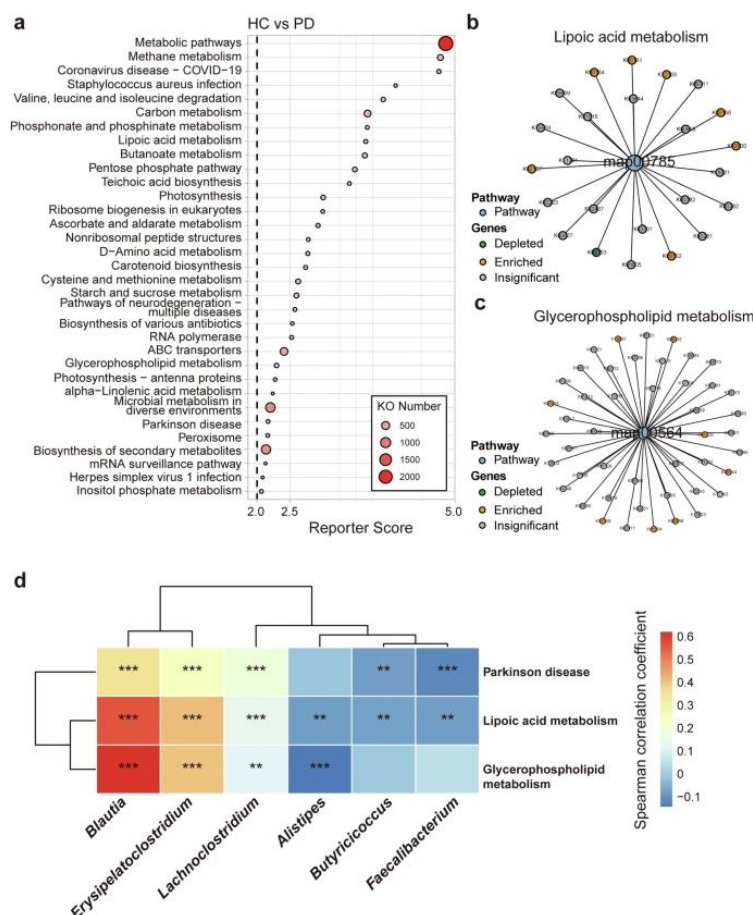


Figure 2 Changes in microbial functions of PD (Adopted from Zhao et al., 2024)

Image caption: (a) Reporter score for level-3 KEGG pathways showing functional enrichment in different groups; Reporter Score>0 represents enrichment of pathways in PD group, and Reporter Score=2 was set as the threshold for visualization; Network plots for (b) lipoic acid metabolism and (c) glycerophospholipid metabolism pathways; d Heatmap showing the associations between genus-level relative abundances and pathway abundances; The color gradient indicates the Spearman's rank coefficient of correlation; ** $P < 0.01$; *** $P < 0.001$; Statistical significance was calculated by Spearman correlation test (Adopted from Zhao et al., 2024)

During intestinal biopsy, α -synuclein deposition in the enteric nervous system is studied as an early diagnostic marker, but this examination is invasive and difficult to popularize (Qian et al., 2020). Non-invasive detection methods such as the tongue membrane microbiota have become good alternatives (Yang et al., 2025). Combining indicators from multiple sources is expected to further enhance the accuracy of diagnosis and monitoring of Parkinson's disease (PD).