How microbes living in the gut affect the brain and behaviour

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Researchers at the University of Oxford have proposed an evolutionary framework to understand why microbes living in the gut affect the brain and behaviour, published in *Nature Reviews Microbiology*. Katerina Johnson (Department of Experimental Psychology) and Kevin Foster (Department of Zoology) assessed data from studies on the gut-brain axis to suggest how that gut feeling evolved.

Research has shown that gut bacteria (especially species belonging to Lactobacillus and Bifidobacterium) can influence social behaviour, anxiety, stress and depressive-like behaviour. Katerina explained: "We know there are numerous possible mechanisms, including communication via the vagus nerve (major nerve linking the gut and brain), the immune system and hormonal changes, as well as the production of neuroactive chemicals by gut microbes. But why should we expect gut bacteria to affect behaviour at all?" In their paper, Johnson and Foster consider the evolutionary pressures that may have led to that gut feeling.

One theory gaining momentum is that members of the gut microbiome actively manipulate our behaviour for their own benefit. For instance, gut bacteria might change our behaviour in ways that make us more sociable to increase their likelihood of transmission to new hosts. Indeed, it is intriguing that numerous species of gut bacteria can produce chemicals of identical structure to our brain's own neurotransmitters (or their precursors). However, in light of evolutionary theory, the authors suggest this scenario, that our brains are manipulated by our microbes, is

very unlikely given the immense diversity of microbial species and strains inhabiting the gut. Professor Foster explained: "Any extra energetic cost invested by bacteria producing a neuroactive chemical to manipulate host behaviour would make it very vulnerable to being outcompeted by other microbes not making this additional investment. The conditions favouring manipulation appear rarely satisfied by the genetically diverse ecosystem of the mammalian microbiome."

Katerina commented: "Rather than viewing our microbial companions as puppeteers manipulating our behaviour, instead we suggest that the behavioural effects of gut microbes are more likely a result of natural selection on microbes to grow and compete in the gut, and natural selection on hosts to depend on their microbes. Microbial growth gives rise to metabolic by-products such as short-chain fatty acids known to affect brain function and microbial metabolites can also interact with our immune response. In addition, our physiology may have adapted to make use of our associated microbes. Similar to the "hygiene hypothesis," which posits that an absence of microbes impairs immune system development, we propose that we may have evolved to depend on our microbes for normal brain function, such that a change in our gut microbiome could have effects on behaviour." Johnson and Foster suggest that an understanding of the evolution of gut-brain communication may help us to effectively engineer this microbial ecosystem with potential benefits for mental health and well-being.

More information: Katerina V.-A. Johnson et al. Why does the microbiome affect behaviour?, *Nature Reviews Microbiology* (2018). DOI: 10.1038/s41579-018-0014-3

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