Key Stage 5

Gut feeling

Student worksheet

You are actually mostly bacteria. Your body contains around 1 trillion human cells and 10 trillion bacteria. Your gut is home to a dense and diverse community of microbe species – a microbiome. They provide many benefits including protection from disease, nutrition, and helping your immune system develop. They can even affect our mood.

The gut-brain connection

Your gut contains 500 million neurons, which are connected to your brain through nerves in your nervous system. This connection is known as the gut-brain axis.

Maintaining a healthy microbiome could play an important role in good mental health. Current thinking in the field of neuropsychology includes strong speculation that bipolar disorder, schizophrenia, and other psychological problems may be associated with disruption to the microbiome.

A team at The University of Oxford is studying social interactons between microbes and other organisms. The microbiome is a example of a symbiotic relationship (a close relationship between organisms – the symbionts). It is hoped that by finding out more, microbiomes can be engineered to improve human health.

Your task

Read through the extracts from a paper written by researchers at The University of Oxford and answer the questions below.

1. A fungal parasite infects ants https://goo.gl/x52HTm. Use this example to explain how a symbiont manipulates host behaviour for their benefit.

2. The authors argue that is unlikely that symbiont in our microbiome manipulates our behaviour for its benefit. Describe two reasons why they think this.

3. They present the hypothesis that behavioural effects arise because substances produced by the microbes affect the host as a side-effect. Explain how these could affect the brain. Why do humans depend on these substances?

4. Research has been done on germ-free mice who live their whole life with no microbes in their body. These mice have shown behavioural problems. Use this hypothesis to explain why.

5. Outline how the findings reported in this paper can lead to developments in improving human mental health.

http://www.oxfordsparks.ox.ac.uk/content/bacteria-safari-forest-your-fingernail
Why does the microbiome affect behaviour?

Katerina V.-A. Johnson and Kevin R. Foster

Abstract | Growing evidence indicates that the mammalian microbiome can affect behaviour, and several symbionts even produce neurotransmitters. One common explanation for these observations is that symbionts have evolved to manipulate host behaviour for their benefit. Here, we evaluate the manipulation hypothesis by applying evolutionary theory to recent work on the gut–brain axis. Although the theory predicts manipulation by symbionts under certain conditions, these appear rarely satisfied by the genetically diverse communities of the mammalian microbiome. Specifically, any symbiont investing its resources to manipulate host behaviour is expected to be outcompeted within the microbiome by strains that do not manipulate and redirect their resources into growth and survival. Moreover, current data provide no clear evidence for manipulation. Instead, we show how behavioural effects can readily arise as a by-product of natural selection on microorganisms to grow within the host and natural selection on hosts to depend upon their symbionts. We argue that understanding why the microbiome influences behaviour requires a focus on microbial ecology and local effects within the host.

Fig. 1 | Evolution of microbial effects on the brain. Arrows denote the potential routes by which microorganisms may influence host behaviour. Effects driven by natural selection on members of the microbiota are shown in blue. The left-hand side captures microbial manipulation, in which case the effects on the host increase microbial fitness. Here, the microbiota–gut–brain axis arises as an evolutionary adaptation of microorganisms to influence either the gut environment (local manipulation of host physiology) or host behaviour (global manipulation of the host). The right-hand side depicts the evolution of microbial traits that affect the brain without the evolution of manipulation. For example, the evolution of the metabolism used by the microbiota to survive and divide in the gut may generate compounds, such as metabolic waste products, that affect host behaviour as a side effect. In this case, the compounds are not adapted to influence the host, and host effects are a by-product. Effects driven by natural selection on the host are shown in purple. The host may evolve to depend on the microbiota for particular functions, including nutrient provision or immune system maturation, such that a missing microbial species leads to...
strong physiological effects and, potentially, behavioural effects. In addition, natural selection is expected to favour hosts that use the microbiota to provide information on nutrition and health in a manner that influences feeding, foraging and sickness behaviour. In all cases, the effects of the microbiota may be due to multiple mechanisms, including the production of neuroactive chemicals that then trigger the **vagus nerve** or travel to the brain through the blood or **lymphatic system** or through effects on the immune system.

**Fig. 2 |** How neurotransmitters in the gut **lumen** might influence the central nervous system. Several neurotransmitters have been isolated from microbial species known to occur in the human gut (see examples in grey box). The microbial production of neurotransmitters represents a potential mechanism to directly influence the brain and behaviour. In reality, this route is limited because most neurotransmitters, including serotonin, dopamine and GABA, cannot typically breach the protective **blood–brain barrier**. Alternative modes of action include the possibility that microorganism-derived neurotransmitters affect the brain through the vagus nerve and its **afferent neurons**. Another option is that precursors of neurotransmitters cross the blood–brain barrier and are then converted into active neurotransmitters. For example, gut bacteria can influence the metabolism and availability of the serotonin precursor tryptophan. This may affect serotonergic signalling in the central nervous system as tryptophan concentration in the blood plasma has been shown to correlate with brain serotonin levels.

Read the rest at

[https://zoo-kfoster.zoo.ox.ac.uk/sites/default/files/files/Johnson%20Foster%202018.pdf](https://zoo-kfoster.zoo.ox.ac.uk/sites/default/files/files/Johnson%20Foster%202018.pdf)