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PERSPECTIVE

The Conceptual Ecology of "Dysbiosis"

David Kelley[1]

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Abstract
"Dysbiosis" is a common but vague term featured in the microbiome literature, often invoked to indicate some kind of imbalance among microbiota. There is no agreement on how to define or even characterize dysbiotic microbiomes. Building on the work of Morar and Bohannan, who explore five interpretations of "microbiome," I offer a short supplemental analysis of what plausibly counts as "dysbiosis" according to each of the five distinct conceptions. My aim is to provide a more nuanced basis for interpreting claims, primarily and most generally; and more specifically, provide a basis for those advancing pluralist or eliminativist arguments.

Keywords Dysbiosis · Microbiome

Introduction

"Dysbiosis" is a common but vague term featured in the biological literature regarding microbiomes. There is no agreement on how to characterize dysbiotic microbiomes, and attempts to do so are often inconsistent or circular (Hooks and O'Malley 2017; Lynch et al. 2019). So then, what does it mean to say a microbiome is in a state of dysbiosis? Presumably, this depends on how we are thinking about the microbiome.

In a recent paper, Morar and Bohannan (2019) explore five conceptions of the microbiome, likening it to or classifying it as an organ; part of the immune system; a superorganism; part of a holobiont; and as an ecological community (or communities) within an ecosystem. Building on their work, I offer a short supplemental analysis of what plausibly counts as "dysbiosis" according to each of the five conceptions: as a malfunctioning organ; failure in immune defense; deficiency of superorganismic unity; holobiont maladaptedness; and ecosystem collapse. I do not evaluate the utility or correctness of each sense explored, nor argue for one over the others. Rather, I simply offer a plausible interpretation of dysbiosis on each of the five conceptions of the microbiome. My aim is to offer tools for achieving more precision when both invoking, and critiquing the invocation of, this ubiquitous and slippery concept. This work is motivated by the fact that common notions of dysbiosis are conceptually dependent on notions of the microbiome.

Five Interpretations of "Dysbiosis"

1. Dysbiosis as malfunctioning microbiome

Like an organ, the microbiome takes up space within our bodies—collectively the size of a liver (Velio 1992, p. 251)—and performs functions (for example, digestion). When viewed as an organ, dysbiosis implies that the microbiome is functioning suboptimally, malfunctioning, or at its worst, failing entirely (i.e., "organ failure"). On this way of thinking about the microbiome, dysbiosis conveys a sense in which our microbiota are not properly doing their job. As a result, we might expect negative downstream effects for the entire organ system. Conversely, dysbiosis may indicate the microbiome *is* the downstream organ—that is, the organ negatively affected by deficiencies elsewhere in the system (similar to how, for example, a poorly pumping heart can lead to blood congestion within the kidneys).

2. Dysbiosis as a failure of immune defense

✉ David Kelley
dkel960@aucklanduni.ac.nz

[1] School of Humanities, University of Auckland, Auckland, New Zealand

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Our immune system acts in recognition of the borders between us and the world, maintaining those borders by rejecting what doesn't belong (whether of endogenous or exogenous origin; Pradeu 2012). As part of the human immune system, our microbiome has a role to play in weeding out pathogens. Our microbiota also play a role in stimulating development of other parts of our immune system (Morar and Bohannan 2019, p. 153). On this view, dysbiosis can plausibly be understood as indicating a weak or less than robust immune response. Dysbiosis may therefore precede illness or be indicative of a taxed immune system struggling to fend off an invasion of colonizing pathogens.

3. Dysbiosis as a deficiency of superorganismic unity

The term "superorganism" refers to a group of organisms that cooperatively interact such that they collectively exhibit the traits of a single higher-level organism. For example, in eusocial insect colonies, we observe a tight functional integration and division of labor, including castes that reproduce and castes that do not (comparable to germ and soma cells in a multicellular organism). Dysbiosis, on the superorganism conception of the microbiome, would indicate that the microbiome's functional organization is out of sorts. This could be due to low levels of cooperation or an over/under abundance of some microbial taxa that negatively affects microbiome functional organization. Dysbiosis could be an indication that "normal" channels of communication and coordination among microbes have, in some way, been hindered such that the otherwise expected collective effects of the superorganism might not be observed or are observed to be irregular.[1]

4. Dysbiosis as holobiont maladaptedness

The microbiome might also be considered a symbiont that has coevolved with its human host, together comprising an evolutionary unit called a "holobiont" (this is one view of what a holobiont is; another view is that a holobiont is an ecological community (Skillings 2016; Suarez and Stencel 2020). The ecological view will be explored below).[2] Human–microbe interactions affect the fitness of both, and more to the point, the whole. Both the genes and microbiota of the host can be transmitted from parent to offspring. Dysbiosis, on the holobiont view, might be understood as a trait with the potential to negatively affect holobiont fitness. To be in such a state would mean that host–microbe interactions or holobiont–environment interactions result in ways that may be detrimental to both microbes and host.

5. Dysbiosis as ecosystem collapse

An ecosystem is composed of a biological community and its environment. In the case of the microbiome, the host is the environment, and the microbes make up the community. A flourishing microbe–host ecosystem may provide us (i.e., human hosts) with beneficial "ecosystem services," for example, positive health effects. However, the opposite is also true. In the latter case, "dysbiosis" can plausibly refer to a lack of ecological resilience, species richness, or functional diversity. It may indicate an ecological collapse following the dwindling of a keystone species or the result of an "environmental catastrophe" (for instance, following a course of antibiotics).

Why are these Distinct Conceptions of "Dysbiosis" Useful?

The foregoing can serve as a basis for a few different ways to forward this conceptual debate. I will sketch three:

1. Offering distinct interpretations of "dysbiosis" (e.g., for the charitable reconstruction of claims).
2. The recognition of multiple senses of "dysbiosis" (e.g., where more than one might be seen as useful or legitimate).
3. Arguments that all five of the above interpretations of "dysbiosis" are insufficient, unhelpful, or misleading (prompting, for instance, a call to eliminate the concept).

I will say a bit more about each of these.

Firstly, claims about dysbiosis might usefully be indexed to the five interpretations offered above (and perhaps others). In cases where "dysbiosis" is thought vague, we can draw upon the five characterizations above to interpret claims, essentially swapping the problem of vagueness for the more manageable problem of ambiguity. For example, one might inventory various claims throughout the literature where dysbiosis is described in terms of improper functioning. In this case we could draw on interpretations 1 and 5 (organ and ecosystem, respectively) to offer a more informative and thorough evaluation of such claims by distinguishing evolutionary and ecological understandings of "function." We make progress by showing which combination of interpretations and claims are consistent, and which are inconsistent.

[1] For example, a breakdown in expected processes of microbe-mediated nutrient transport. Thanks to Emily Parke.

[2] In other words, *if* we think of holobionts as evolutionary units, then we could conceptualize dysbiosis as holobiont maladaptedness. Those who do not share this view would prefer to talk about this interpretation in a different way, for example, "Dysbiosis as Problems for the Holobiont" (not problems for holobiont fitness).

Secondly, one may reflect on the five interpretations above and conclude the need for categorical complexification. That is, reflecting on the competing *interpretation*s of "dysbiosis" may prompt the acknowledgement or adoption of numerous *senses* of dysbiosis. This opens the way for a more nuanced conceptual debate about which senses of "dysbiosis" are useful in different contexts. For those who think two or more of the interpretations above are legitimate or useful, a pluralist approach may be argued. Making this move means taking the distinct *senses* of dysbiosis and reconceptualizing them as distinct *satisfying conditions* for dysbiosis.

Lastly, some may think all five interpretations above are lacking, misrepresentative, or otherwise insufficient. That is, the inventory above may give some reason to argue that we still lack any worthy conception of dysbiosis. One may conclude that this insufficiency calls for more conceptual work on dysbiosis. Alternatively, one may call for eliminating the notion of "dysbiosis" all together. In the case where one feels that "dysbiosis" is a vacuous and vague concept for which there is no sensible candidate referent, then perhaps the most appropriate thing to do is purge our discourse of this confused notion.

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Declarations

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