



Biomedicine

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Community communities: what we can learn from microbes

The idea that microbes are isolated pathogens or merely invisible agents of disease has long been replaced by the understanding that microorganisms form complex, highly structured communities that colonise all known environments and establish interactions with virtually every living organism. Microbial communities and their interactions with the human host are a central object of study in Biomedical Sciences at the Faculty of Dental Medicine of the Universidade Católica Portuguesa. Research on how microbial communities are organised to survive, adapt, and thrive has greatly improved the way we prevent and treat human disease, but it can also provide valuable insights into the fundamental principles that underlie functional collectives in general. We argue that lessons learned from the microbe world might help us create sustainable and resilient communities free from destructive conflict, misinformation and extremism.

One of the most important traits observed in microbial communities is cooperation and division of labour. In many microbial ecosystems, cooperation is essential, and individual species or cells specialise in specific tasks that benefit the whole community. For example, in the oral microbiome, host-derived molecules such as salivary mucins are efficiently degraded by nutritional guilds in which each microbial species produces specific enzymes that target particular components of the molecule. This metabolic cooperation allows several microbial species to survive in the oral cavity even during fasting, when no external nutrients are available (1). For human societies, this highlights the importance of collaboration and specialisation. Complex contemporary challenges

– such as public health, environmental sustainability, or scientific innovation – are addressed more effectively through coordinated efforts in which individuals contribute complementary skills rather than compete to perform identical roles (2).

Efficient communication underlies successful collaboration, and microbial communities communicate remarkably well through mechanisms such as quorum sensing. Through this process, bacteria sense population density and coordinate group behaviours, including biofilm formation, production of virulence factors, or bioluminescence. These actions are initiated only when the community reaches a critical size, ensuring that collective behaviour is effective rather than wasteful. For human communities, this illustrates the importance of information sharing and coordination. Effective communication allows groups to act collectively, make informed decisions, and adapt strategies based on feedback, rather than relying on uncoordinated individual actions. Microbes also show that one way to disrupt a community is by interfering with communication, as illustrated by several examples of quorum quenching (3).

Another major lesson from the living world, and not only from microorganisms, is that diversity increases community resilience. When different species occupy distinct ecological niches and provide overlapping functions (a phenomenon known as functional redundancy) communities are better able to withstand environmental disturbances. If one individual or even an entire species is lost, another may compensate, preserving the overall function of the system. Human societies similarly benefit from diversity in skills, perspectives, and experiences. Diverse communities tend to be more innovative, adaptable, and resistant to social or economic shocks than homogeneous ones (2).

Microbial communities also remind us that competition and conflict are unavoidable aspects of communal life. In microbial ecosystems, competition for limited resources is common, and the production of antibiotics or toxins to inhibit rivals is frequently observed. In the human body, this competition is one of the benefits of maintaining a healthy symbiotic microbiome, as resident microbes can exclude opportunistic and pathogenic species. While competitive behaviour helps structure microbial communities and can benefit the host, it can also lead to destructive arms races in which neither competitor ultimately benefits.

For human societies, this serves as a cautionary lesson. Competition can drive innovation and efficiency, but when it becomes excessive or destructive, it undermines long-term stability and collective well-being. Human societies must therefore regulate competition through ethical norms, laws, and institutions to prevent it from escalating into harmful conflict.

Perhaps one of the most powerful lessons from microorganisms arises from their relationship with their hosts. Humans and their microbiota form a deeply interdependent system, in which both sides benefit when balance is maintained. Microbes gain nutrients and a stable habitat, while the host benefits from metabolic support, immune regulation, and protection against unwanted colonisation. When this balance is disrupted (a state known as dysbiosis) disease may occur. This relationship illustrates the importance of caring for the systems on which we depend. Human communities, like microbial ones, rely on healthy “host environments,” including ecosystems, economies, and social institutions. Exploiting these systems without regard for sustainability risks long-term collapse, a concern clearly emphasised by Pope Francis in *Laudato Si'*, which calls for care of our common home (4).

Microorganisms are, quite literally, small actors with an enormous collective impact. On a global scale, microbial-driven biogeochemical cycles demonstrate that large-scale change often arises from the cumulative effect of many small contributions. As a society, and particularly as higher education institutions, we have a responsibility to raise awareness of individual responsibility within collective action when addressing global challenges, such as those articulated in the United Nations Sustainable Development Goals (5).

Not all principles governing microbial communities are positive models for human organisation. Harmful behaviours also exist in the microbial world. Pathogenic microorganisms may exploit their hosts aggressively, causing damage that ultimately threatens both host and microbe. This mirrors unsustainable human behaviours that prioritise short-term gains over long-term stability. Furthermore, microorganisms can rapidly spread harmful traits through horizontal gene transfer, a process that finds parallels in the rapid dissemination of misinformation or destructive social norms in human societies. These examples highlight the need for critical reflection when drawing analogies between microbial and human communities.

Microbial communities provide a rich source of insight into how collective systems function. They teach us the importance of cooperation, communication, diversity, adaptability, and balance, while also reminding us of the dangers of unchecked competition, exploitation, and rigidity. By studying microorganisms not merely as isolated entities but as members of complex communities, we gain a deeper understanding of the principles that sustain life at all scales. Ultimately, microorganisms remind us that thriving communities (whether microbial or human) are built not on individual dominance, but on interconnectedness, balance, and mutual dependence.

References

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