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Biofilm Dynamics: Interdisciplinary Insights into Microbial Interactions within the Context of Microbiomes and Host Health.

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Introduction

Biofilms—structured communities of microorganisms encased in a self-produced extracellular matrix—are among the most resilient and complex forms of microbial life. Found on virtually every surface, from medical devices to mucosal tissues, biofilms play a pivotal role in shaping microbial interactions within microbiomes and influencing host health [1, 2].

Their dynamics are governed by intricate interspecies communication, environmental cues, and host factors, making them a central focus of interdisciplinary research spanning microbiology, immunology, ecology, and biomedical engineering. Understanding biofilm behaviour is essential not only for managing chronic infections but also for harnessing beneficial microbial communities in health and disease prevention [3, 4].

Biofilm formation occurs in distinct stages: initial attachment, micro colony formation, maturation, and dispersion. During these phases, microbes secrete extracellular polymeric substances (EPS), which form a protective matrix composed of polysaccharides, proteins, lipids, and extracellular DNA [5, 6].

This matrix provides structural integrity, facilitates nutrient exchange, and shields microbes from environmental stressors. Multispecies biofilms are common in natural and host-associated microbiomes. In these communities, microbial interactions range from cooperation (e.g., metabolic cross-feeding) to competition (e.g., bacitracin production), influencing biofilm architecture and function [7, 8].

Microbes within biofilms communicate through quorum sensing (QS)—a cell-density-dependent signaling mechanism that regulates gene expression. QS molecules, such as acyl-homoserine lactones in Gram-negative bacteria and auto inducing peptides in Gram-positive bacteria, coordinate behaviours like virulence, biofilm maturation, and antimicrobial resistance [9, 10].

Conclusion

Interspecies and intraspecies interactions can be positive (mutualistic), negative (antagonistic), asymmetric, or neutral, shaping the biofilm's ecological balance. For example, *Pseudomonas aeruginosa* and *Staphylococcus aureus* exhibit competitive interactions in polymicrobial biofilms, influencing infection severity and treatment outcomes.Biofilms are integral to host-associated microbiomes, including those in the oral cavity, gut, skin, and respiratory tract. In the gut, biofilms contribute to microbial stability and barrier function, while in the oral cavity, they form dental plaque—a biofilm implicated in caries and periodontal disease.

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