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Commentary

The Role of Bacteriophages in Microbial Ecology and Therapy

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DESCRIPTION

Bacteriophages, often referred to as phages are viruses that infect and kill bacteria. These microscopic entities are the most abundant and diverse biological agents on Earth existing in various ecosystems. Bacteriophages play an essential role in regulating microbial communities, bacterial evolution and maintaining ecological balance. In recent years, they have also emerged as a promising alternative to antibiotics, particularly in the context of Antimicrobial Resistance (AMR).

Bacteriophages are central to maintaining microbial diversity and balance in ecosystems. By infecting and lysing bacteria, they influence the structure, function and evolution of microbial communities. Their ecological role can be understood through several key processes. Phages act as natural predators of bacteria, controlling bacterial abundance and preventing the dominance of specific strains. This "top-down" control prevents bacterial overgrowth, thus supporting the diversity and stability of microbial communities. For example, in aquatic environments like oceans and lakes, phages infect marine bacteria, releasing organic carbon, nitrogen and phosphorus into the water. This process, known as the viral shunt, redirects nutrients back into the microbial loop promoting the growth of other microorganisms.

Bacteriophages exert selective pressure on bacterial populations, driving evolution through a process called Red Queen dynamics. As phages evolve to become more efficient at infecting bacteria, bacteria, in turn, develop resistance mechanisms. This constant "arms race" shapes bacterial genomes, contributing to microbial evolution and diversity. Horizontal Gene Transfer (HGT) *via* phages is another important evolutionary mechanism. Transduction, the process where phages transfer bacterial genes from one host to another, promotes the exchange of genetic material facilitating adaptation to changing environmental conditions.

Bacterial biofilms are communities of bacteria enclosed in a protective matrix, making them highly resistant to antibiotics. Phages, however possess the ability to penetrate biofilms and infect bacteria within them. They produce enzymes such as depolymerases, which degrade the extracellular matrix, enabling phages to access and kill bacteria. This process not only disrupts biofilms but also creates niches for new bacterial species to colonize, increasing microbial diversity. Phage-mediated biofilm disruption has applications in health care and industry, where biofilms are a persistent problem on medical devices, pipes and water systems.

In aquatic and terrestrial ecosystems, phages play an essential role in biogeochemical cycling. By lysing bacteria, they release Dissolved Organic Matter (DOM), making nutrients like carbon, nitrogen and phosphorus available for other microorganisms. This "viral shunt" has many implications for carbon cycling in oceans, as phage-induced lysis releases carbon that would otherwise be consumed by higher trophic levels. This process also influences global climate regulation, as oceans serve as a major carbon sink. With the rise of Antimicrobial Resistance (AMR), bacteriophages are being used as an alternative to antibiotics. Phage therapy involves the use of bacteriophages to target and kill specific bacterial pathogens. While phage therapy has been used since the early 20^{th} century, interest in this approach has started again due to the limitations of antibiotics in treating infections.

Phage therapy works by exploiting the phage's natural ability to recognize and attach to specific bacterial receptors. Once attached, the phage injects its genetic material into the bacterial cell and making its machinery to produce new phage particles. As the bacterial cell fills with phage progeny, it undergoes lysis (cell rupture), releasing new phages that infect neighboring bacteria. Since each phage targets a specific bacterial species, phage therapy is considered a narrow-spectrum treatment, unlike broad-spectrum antibiotics that indiscriminately kill beneficial and harmful bacteria.

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